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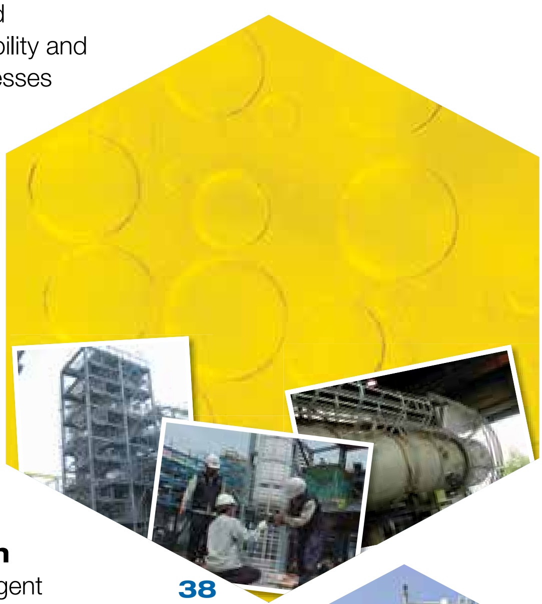
38


14


20


52

58

65

25

30

Equipment and Services

Departments

Advertisers

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Editor's Page

Preparing for unprecedented storms

This year, hurricane season in the U.S. has been active again, with Hurricane Florence battering North Carolina and its surroundings last month. While wind speeds labeled it as a Category 1 hurricane at landfall, the enormous, slow-moving storm caused great damage, and tragically, loss of life. At the time of this writing, the event has been downgraded to a tropical storm, but the relentless rain and the storm-related tornadoes are continuing to wreak havoc in multiple states, even far inland from the original site of landfall.

Flooding

Scenes of the record-setting, unprecedented flooding caused by Florence — homes, roads and vehicles submerged under water, and people and pets being rescued in boats — are reminiscent of the scenes we witnessed last year with the also unprecedented flooding from Hurricane Harvey in the Gulf Coast. Flooding can cause serious safety concerns and consequences for industrial facilities. At the time of this writing, for example, there are reports that Florence's heavy rain caused a collapse of a coal-ash landfill at a former coal-fired power plant (closed since 2013) in North Carolina. Concerns are that the coal ash could contaminate nearby waterways.

Last year, record-setting flooding from Hurricane Harvey caused failures of several safety systems at Arkema's Crosby, Texas plant that ultimately led to fires and explosions of temperature-sensitive organic peroxides when cooling capabilities were lost. Twenty-one people who were exposed to vapor from the decomposing peroxides on a nearby public highway sought medical attention, and more than 200 people were evacuated from within a 1.5-mile radius around the plant.

While safety systems were in place and safety plans were followed at the Crosby site, they were insufficient for the unprecedented extreme flooding that occurred. In its final report on this incident that was issued earlier this year,* the U.S. Chemical Safety Board (CSB; www.csb.org) said that "other companies also might be unaware of the potential for flood risks to create process safety hazards at their facilities if flood-related information is not typically compiled or assessed in required safety analyses." And understanding flood-plain elevations and historical flooding events at facilities may be more important than ever. According to the CSB report, "In recent years, flooding from extreme rainfall events has increased and according to a 2015 EPA report, this trend is projected to continue . . ." The CSB report offers several recommendations, including the development of more comprehensive guidance for extreme weather events, which do appear to be happening more frequently.

Another precedent

Another unprecedented outcome from Hurricane Harvey is the indictment this August against Arkema's chief executive and the Crosby plant manager for the events that took place. The American Chemistry Council (ACC; www.americanchemistry.com) stated that this indictment "sets an alarming and unreasonable precedent of seeking to hold people responsible for acts of nature."

While the results of the legal actions have yet to unfold, the seemingly more-frequent extreme weather that is being experienced globally calls for a re-assessment of what can be done to better prepare for unprecedented events. ■

Dorothy Lozowski, Editorial Director

*www.csb.gov/arkema-inc-chemical-plant-fire-/

Advanced ODC electrolysis reduces energy consumption even more

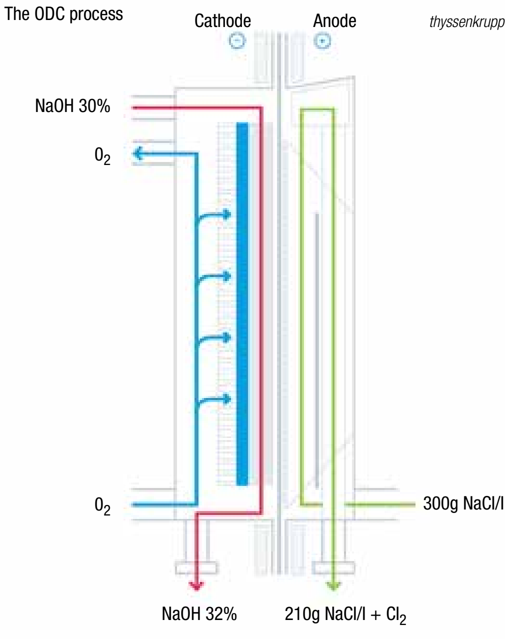
Edited by:
Gerald Ondrey

Around 70% of all chemical products use chlorine in their manufacturing process. At the same time, the production of this important base chemical is one of the most energy-intensive processes in the chemical industry. In order to change that, thyssenkrupp Industrial Solutions AG (Essen, Germany; www.thyssenkrupp-industrial-solutions.com) is offering the NaCl-ODC (oxygen depolarized cathode) electrolysis technology, which lowers power consumption and indirect CO_2 emissions by up to 25% compared to standard chlor-alkali processes.

Now, thyssenkrupp engineers have been able to further develop the technology: by raising the current density of the electrolyzer from 4 kA to 6 kA, output was increased by 50%. Electrolyzers with the same output capacity can now be built about one third smaller, resulting in significantly lower total cost of ownership, says the company.

Thyssenkrupp's cooperation partner Covestro AG (Leverkusen, Germany; www.covestro.com) will be the first to utilize the advanced ODC electrolysis for a new chlor-alkali plant in Tarragona, Spain.

Energy consumption makes up roughly one third of the operating expenses of a chlor-alkali production plant. Thus, the advanced NaCl-ODC technology helps to significantly reduce energy costs. Compared with the conventional single-element design, it will cut CO_2 emissions of the Tarragona plant by around 22,000 metric tons per year (m.t./yr).



$$2\,NaCl + H_2O = 1/2\,O_2 \rightarrow Cl_2 + 2\,NaOH$$

Thyssenkrupp successfully commissioned the first large-scale reference for this technology at the end of 2015 for BEFAR Group in China.

Advanced thermal hydrolysis pretreatment boosts biogas production

Thermal hydrolysis of wastewater sludge before it enters anaerobic digestion units can increase the rate of residuals-to-biogas conversion and increase the feed concentration, the combination of which significantly reduces anaerobic-digester reactor volume. An advanced thermal hydrolysis process (THP) is being installed as part of the Washington Suburban Sanitary Commission's Piscataway Water Resource Recovery Facility bio-energy project in Prince George's county, Maryland. The facility will be among the first in the nation with such an advanced THP system.

"THP pretreatment changes the nature of the substrate going into the digester, and it increases the reaction rates, so the digesters can be loaded at higher concentrations, leading to biogas produced at a faster rate," explains Dru Whitlock, global practice leader for biosolids and energy recovery with Stantec (www.stantec.com), the engineering firm designing the project as part of a design-build team with PC Construction and Hazen and Sawyer.

With THP pretreatment, unstabilized wastewater residuals are fed into a series of batch reactors in parallel, where the sludge is heated to 165°C at elevated pressures (90–100 psi). The treatment improves the rate kinetics of the sludge, thus boosting the subsequent performance of the anaerobic digester. In addition, the dewaterability, reduced odor content, and significantly reduced pathogen content allow it to be safely reused. In some cases, the amount of residuals converted to biogas increases, thus allowing more energy recovery.

Phase One of the project is now underway, which includes design and early construction involving demolition of existing on-site facilities and relocation of existing utilities. The facility is expected to be operational by spring 2024.

NEW ADSORBENT

Last month, BASF SE (Ludwigshafen, Germany; www.basf.com) launched Sorbead Air, an efficient adsorbent for drying compressed air. The adsorbents are hard, spherical beads of alumino-silicate gel that resist abrasion. Due to the beads' large surface area and pore volume, which increases adsorption capacity, Sorbead Air offers higher water uptake at varying levels of humidity than other commercial products. It also requires lower temperatures during regeneration. The adsorbent is said to have a long lifespan (7–10 years), which can result in decreased dryer downtime and refill-cost savings of up to 40%. Users can save up to 8.5 kWh per hour and more than 20% of the total cost to run the compressed air systems, according to Brian Houston, global business director, BASF Adsorbent Solutions.

ENSEMBLE CATALYST

A South Korean team has developed a fully dispersed Rh ensemble catalyst that exhibits superior low-temperature activity in CO, NO, propylene and propane oxidation at low temperatures, compared to commercial diesel oxidation catalysts. The new catalyst can therefore be used for low temperature treatment of automobile exhaust.

The team includes staff from the Korea Advanced Institute of Science and Technology (Daejeon; www.kaist.ac.kr), Pohang University of Science and Technology (www.postech.ac.kr) and the University of Seoul (Seoul; www.uos.ac.kr).

Automobile exhaust gas pollutants, such as propylene and propane, must be converted to CO_2 and water before they are released as exhaust. Since the hydrocarbon oxidation reactions proceed only during carbon-carbon or

(Continues on p. 8)

carbon-hydrogen bond cleavages, it is essential to secure a metal ensemble site. This, therefore, requires metal catalysts with high dispersion and ensemble sites.

The new catalyst has 100% dispersion, so that every metal atom is used in the reaction. Single-atom catalysts also have 100% dispersion, but the new catalyst has the unique advantage of having an ensemble site with two or more atoms. This overcomes the disadvantage of nanoparticle catalysts, which perform poorly at low temperatures due to low metal dispersion, and of single-atom catalysts that do not act as catalysts for reactions that require ensemble sites.

The team prepared the Rh catalysts by treating 2 wt.% Rh/CeO_2 hydrothermally at 750°C for 25 h. During the treatment, the Rh size increased initially from 2.3 nm to 6.7 nm, then decreased to 0.9 nm. The hydroxyl groups formed on the catalyst surface help detach Rh atoms from Rh clusters, while preventing the reaggregation of dispersed Rh atoms into Rh clusters.

ADVANCED CLEANER

Houghton International Inc. (Valley Forge, Pa.; www.houghtonintl.com) has developed Houghto-Rinse RTD, an advanced cleaner that can be used as a direct replacement for highly volatile solvents in applications where flammability, health, safety and environmental factors are concerns. It is designed to remove surface residues, such as spray paint, marker pen, ink, glue, grease and production soil, prior to final inspection, assembly or packaging. It is safe for use on all surfaces including aluminum, steel, magnesium, plastics, painted surfaces, and fiberglass. Its cleaning effectiveness and non-residue properties make it particularly valuable for critical cleaning applications where surface appearance is important, says the company.

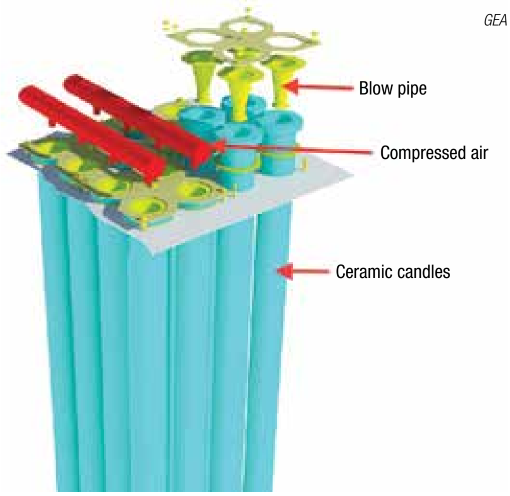
H_2-GENERATION RECORD

A half-cell, solar-to-hydrogen conversion efficiency of 12.5% has been achieved using a photocathode developed by the Japan Technological Research Association of Artificial Photosynthetic Chemical Process (ARPChem), New Energy and Industrial Technology Development Organization (NEDO, Kawasaki City; www.nedo.go.jp) and the University of Tokyo. The photocathode is composed of thin layers of $CuIn_{1-X}Ga_XSe_2$ [CIGS; where X = Ga/(In + Ga)], which

(Continues on p. 9)

A compact system cleans fluegas from glass-melting furnaces

Furnaces used in the production of glass are normally equipped with fluegas-cleaning plants that have separate steps for the treatment of particulate matter, acid crude gases and oxides of nitrogen (NOx). GEA Group AG (Düsseldorf, Germany; www.gea.com) has developed a technology that performs all these tasks in a single step, in a single reactor. The fluegas is cleaned using ceramic candles — rigid filter elements consisting of coated mineral fibers (diagram). These candles are well-proven and very flexible to use, even with regard to modifications of operating parameters, especially at high gas temperatures. Even stricter future requirements set in German Federal Administration's Regulation "Technical Instructions on Air Quality Control (TA Luft)" will be underrun, says GEA. Dust emissions are reduced to near detection limit, the company adds.



Although GEA has already delivered plants of this kind for the purpose of hot-gas filtration, the company has now recently refined these plants in order to include deNOx capabilities, under the tradename BisCat (Bischoff Catalysator). The ceramic candles are installed in a walk-in clean gas chamber to ensure easy access for maintenance and inspection.

The BisCat technology will be introduced at glasstec 2018 (October 23–26; Düsseldorf). The first commercial system has been ordered by Glashütte Freital GmbH (www.glas-freital.com) for use in its new 150 ton/d glass-melting furnace. The new furnace, along with GEA's emission control plant, is scheduled to be commissioned in March 2019.

Extracting gold without cyanide

The first gold using a process without cyanide and without mercury has been produced using technology from CSIRO Minerals Technology (www.csiro.au) at a demonstration plant in the Western Australian goldfields town of Menzies.

Cyanide is used in more than 90% of global gold production, but producers are facing increasingly tough regulations restricting the use of cyanide due to environmental and health concerns. The CSIRO technology replaces cyanide with thiosulfate, a nontoxic, mobile-plant alternative. It is a simple vat-and-heap-leach process involving low capital cost. CSIRO gold processing team leader Paul Breuer says the CSIRO process targets small high-grade deposits with good gold liberation at a coarse grind size suitable for the gravity tails to be vat-leached. A tank-leach process using this leach system is under development for demonstration next year. This will have the potential to open up the application of the technology to a greater range of ore types and will be scalable to larger projects.

The process concepts entail a mobile plant, vat leach for coarse material, tank leach with thickener/filter as parallel circuit to treat fines, "dry" tails stacking, and plug-and-play modules tailored for different ore types. The mobile plant would allow junior miners and smaller players to process their own gold, explains Breuer. The ability to pack up the plant inside shipping containers gives the process a mobility no other plant could achieve, he says.

The A\$2.1-million (A\$1.00 = \$0.71) demonstration plant at Menzies was made possible through funding from the Science and Industry Endowment fund and an Australian Government Innovation Connections grant. According to CSIRO, a typical cyanide-based processing plant costs about A\$30 million, whereas the new technology involves a capital investment of A\$2–2.5 million.

The CSIRO team behind the innovation has already enjoyed commercial success with another cyanide-free gold solution developed with Barrick Gold for its Goldstrike Mine in Nevada.

Measure bulk solids in piles and silos

Advances in sensing and imaging technologies have enabled new levels of accuracy in the measurement of bulk-solid materials stored in piles, silos and bins. BinMaster (Lincoln, Neb.; www.binmaster.com) and Stockpile Reports (Redmond, Wash.; www.stockpilereports.com) have collaborated to introduce the industry's only proprietary inventory-measurement platform that includes capabilities to process images from drones, smartphones and fixed cameras, combining robust level-sensing technologies with advanced image-processing software.

According to BinMaster, the technology is less expensive and easier to implement than sensing based on light detection and ranging (LIDAR), a commonly used measurement technique. The platform can also provide a confidence interval for measurement accuracy by considering obstructions, such as the presence of standing water, vegetation or extraneous equipment around piles. It can also provide guidance on the effects of these anomalies and recommended maintenance tasks. Typically, pile inventories involving such obstructions require imprecise approximations. Since drones collect images by following a pre-programmed path, taking measurements is streamlined and errors are reduced. In addition to piles and bins, inventory inside of storage bunkers, which are commonly used for fertilizer components, can also be measured.

BinMaster is currently working on enhancing the technology to measure inventory of bulk materials within flat storage warehouses, which typically pose many challenges for sensing and measuring technologies. The warehouse-measurement solution will likely employ a series of synchronized fixed cameras or cameras affixed to conveyors, and is expected to become available in the first quarter of 2019.

are prepared by a three-stage method employing a vacuum evaporation system.

The photocurrent from CIGS photocathode surfaces modified with CdS and Pt (Pt/CdS/CIGS) significantly increased along with *X*, as a result of a reduction in the conduction band offset at the CIGS/CdS interface. Using an optimized aqueous electrolyte resulted in enhanced photocurrents of 28 and 18 mA cm^{-2} at 0 and 0.6 V_{RHE} (RHE = reversible hydrogen electrode) respectively, under simulated AM1.5G sunlight. A tandem-type photoelectrochemical (PEC) cell containing the newly developed CIGS photocathode and a $BiVO_4$ semi-transparent photoanode demonstrated stoichiometric hydrogen and oxygen evolution with a solar-to-hydrogen conversion efficiency of 3.7% — a 3% enhancement over the researchers' 2016 achievement (without the application of an external bias voltage).

SPLITTING WATER

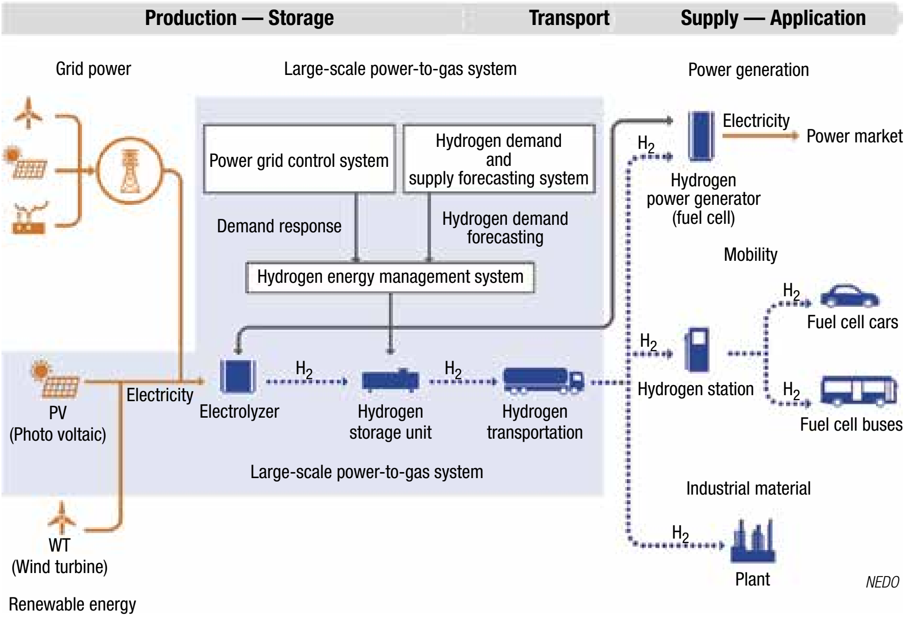
Researchers from the Japan Technological Research Association of Artificial Photosynthetic Chemical Process (ARPChem), the University of Tokyo, Shinshu University and NEDO (see also previous story) have developed the world's first Ta_3N_5 photocatalyst that can split water

(Continues on p. 11)

Japan takes a major step toward a H_2-based economy

A Japanese consortium has started the construction of the Fukushima Hydrogen Energy Research Field (FH2R), which is said to be the world's largest hydrogen-based energy system. Located in Namie-cho, Fukushima Prefecture, FH2R will operate a 10-MW class hydrogen-production facility that will start operation in 2020, after final tests to verify the technologies. Hydrogen produced at FH2R will be used to power fuel cell vehicles and to support factory operations.

The consortium — comprised of the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki; www.nedo.go.jp), Toshiba Energy Systems & Solutions Corp. (Kawasaki; www.toshiba-energy.com), Tohoku Electric Power Co., Inc. (Sendai; www.tohoku-epco.co.jp) and Iwatani Corp.(Tokyo; www.iwatani.co.jp) — aims to contribute to the realization of a hydrogen economy, which is being promoted by Japan's Ministry of Economy, Trade and Industry (METI). METI's guiding policy statement, "Basic Hydrogen Strategy," strives to industrialize the power-to-gas technology for storing surplus renewable energy. The power-to-gas technology utilizing H_2 requires not only a grid balancing function, to make the maximum use of fluctuating renewable energy, but also the optimal system operation function, based on the forecasting of H_2 supply and demand.



H_2, a concentrated energy source that can be stored for long periods and transported over long distances, has emerged as the fuel of choice for fuel cells and fuel-cell vehicles. Its other advantages are that it can be generated with renewable energy sources, and when used as a fuel the only byproduct of which is hot water — a cycle that is expected to be completely CO_2-free.

FH2R will produce (using renewable energy) and store up to 900 ton/yr of H_2. It will use a new control system to coordinate overall operation of the H_2 energy system, the power grid control system, and the H_2-demand-forecast system, so as to optimize H_2 production, H_2-based electricity generation and H_2 gas supply.

The system (diagram) will use H_2 to offset grid loads, and deliver H_2 to locations in Tohoku and beyond, and will seek to demonstrate the advantages of H_2 as a solution in grid balancing and as a H_2 gas supply. Compressed H_2 will be transported in trailers and supplied to users.

Oxidative desulfurization approach for hydrocarbons lowers costs

Petroleum refineries must meet increasingly stringent levels for sulfur content in fuel, but the conventional hydrodesulfurization approach requires high-pressures and temperatures. Alternative Petroleum Technologies Corp. (APT; Reno, Nev.; www.altpetrol.com) has piloted an oxidative desulfurization technology, known as Sulfex, that can remove sulfur from liquid hydrocarbons at near-ambient pressures and temperatures. Eliminating the need for high pressures and temperatures cuts both capital and operating costs for sulfur removal by at least half, says APT.

"The concept of oxidative desulfurization has been around for quite some time, but until now, successfully scaling up the process beyond laboratory scale has proved to be problematic," explains Jack Waldron, APT vice president of engineering. Specifically, Waldron says that early large-scale oxidative desulfurization processes quickly attain equilibrium before adequate sulfur oxidation occurs, limiting its prospective commercial use.

However, in the Sulfex process, sulfur-containing hydrocarbons are oxidized with hydrogen peroxide to form sulfones, which are separated from the hydrocarbon stream, thus avoiding the problems inherent in earlier systems. Taking advantage of its expertise in emulsions, APT has developed a proprietary method that repeats cycles of oxidation and removal of sulfones to drive the reaction toward completion without the use of ultrasonics. The liquid containing the peroxide and other reagents forms an emulsion with the hydrocarbon stream at high mix rates. The emulsion allows the reactions to proceed quickly, but then separates to allow the oxidized sulfur compounds to be removed using a liquid or solid sorbent material, which is then recycled, Waldron says.

The pilot-scale process — which APT has used to remove sulfur from 20 types of hydrocarbon fuels, including diesel, jet fuel and kerosene — was independently verified by Argonne National Laboratory. A large engineering firm affirmed the mass and heat balances. APT is now looking for partners to install the process at commercial scale and is in discussions with a number of oil companies, both in the U.S. and abroad.

using visible light. The achievement is expected to enable the most efficient utilization of sunlight for producing H_2, since visible light accounts for the largest portion of the solar spectrum.

Despite its superior visible-light absorption, Ta_3N_5 photocatalyst has not accomplished overall water splitting due to strong charge recombination at defects. Now, the researchers have solved this problem using nanorods of Ta_3N_5. These nanorods are prepared by rapid growth on lattice-matched cubic $KTaO_3$ particles through the volatilization of potassium species during a brief nitridation process. The Ta_3N_5 nanorods generated selectively on the edge of $KTaO_3$ are spatially separated and well-defined single crystals free from grain boundaries. When combined with the Rh/Cr_2O_3 co-catalyst, the single-crystal Ta_3N_5 nanorods enable the splitting of water into H_2 and O_2 very efficiently under visible light and simulated sunlight. ❑

Materials properties discovery aided by machine learning

A new materials-discovery platform that relies on machine-learning enables scientists and engineers to conduct large-scale searches and predict material properties from atomic structure data. Known as Xaedra, the artificial intelligence platform allows users to define desired properties and quickly identify materials that are likely to exhibit those properties.

"Xaedra allows us to cast a broader 'net' over the materials universe at the beginning," says Charlie Baker, business development director at Lumiant Corp. (Kelowna, B.C.; www.lumiant.com), which recently launched Xaedra. It can help solve difficult materials challenges faster and cheaper than using density functional theory (DFT) modeling calculations, which attempt to solve quantum mechanical wavefunctions for many-atom systems.

In a key advance, Lumiant engineers have developed a way to present atomic crystal structure information about materials in a way that allows known, open-source neural-network algorithms to analyze them. In this way, each crystal structure is given an atomistic "fingerprint" that enables the machine-learning algorithm to be applied, explains Pawel Pisarski, lead developer of Xaedra.

Lumiant has loaded known material properties into its proprietary database, and these properties are used to train the machine-learning system to predict the properties of previously uncharacterized materials. It is done without DFT modeling, which can be time-consuming and expensive, the company says, although future enhancements of Xaedra may apply DFT calculations for further accuracy for some types of predictions.

One initial success of the Xaedra platform was its prediction that the composite material titanium silicide/titanium carbide could be synthesized by self-propagating high-temperature synthesis, a scenario that was not intuitively obvious to researchers. The novel ceramic material is now patented by Lumiant. Xaedra is being used on a host of other projects, including improving metal alloys by sorting and predicting thousands of alloy combinations that would be impractical to test in the laboratory, and in the field of spintronics for computer processors. ■

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Plant Watch

Dow announces investment plans to increase global silicones production

September 12, 2018 — The Dow Chemical Company (Dow; Midland, Mich.; www.dow-dupont.com) will make investments in its global silicones businesses, including plans to build a new hydroxyl functional siloxane polymer plant in Carrollton, Kentucky, which will increase Dow's polymer capacity in the Americas by 65%, and a new specialty resin plant in Zhangjiagang, China, which will provide resin intermediates for high-value silicone products. In addition, the company also announced a series of incremental siloxane debottleneck projects over the next three years, as well as the start of a feasibility study for the construction of a new, world-scale siloxane plant.

Versalis opens new EPDM rubber plant in Italy

September 12, 2018 — Versalis (San Donato Milanese, Italy; www.versalis.eni.com) has opened a €250-million production plant in Ferrara, Italy for ethylene propylene diene monomer (EPDM) rubber, which will mainly supply the automotive industry. This investment in Ferrara will increase Versalis' overall production capacity by around 50,000 metric tons per year (m.t./yr).

Invista to increase capacity for nylon 6,6 polymer in Shanghai

September 12, 2018 — Invista (Wichita, Kan.; www.invista.com) plans to add 40,000 m.t. of nylon 6,6 polymer capacity at its current 150,000-m.t./yr polymer plant at the Shanghai Chemical Industry Park. Construction is targeted for mid-2019 and production would begin in 2020.

Air Products to build world-scale liquid H_2 plant at its La Porte facility

September 12, 2018 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) plans to build a new liquid hydrogen (H_2) plant at its La Porte, Tex. facility. The liquid H_2 plant will produce approximately 30 m.t./d, and is expected to be onstream in 2021.

Methanex to use Johnson Matthey methanol technology for new plant

September 6, 2018 — Johnson Matthey (London, U.K.; www.matthey.com) has been awarded a contract by Methanex Corp. (Vancouver, B.C., Canada; www.methanex.com) to supply a license for a 5,000-m.t./d methanol project, including associated engineering, proprietary equipment and catalyst supply. This is for a new-build unit with a capacity of 1.8 million m.t./yr of methanol. The facility will be located next to Methanex's existing facilities in Geismar, La.

Lanxess doubles production capacity for DMTD specialty additives

September 6, 2018 — Lanxess AG (Cologne, Germany; www.lanxess.com) has commissioned a new production line at its Mannheim site for the synthesis of dimercaptothiadiazole (DMTD) derivatives. These chemicals are added to lubricants as multifunctional additives. The production line doubles the annual production capacity of these specialty additives.

Oxiteno commences operations at Pasadena alkoxylation plant

September 5, 2018 — Oxiteno (São Paulo, Brazil; www.oxiteno.com) commenced operations at its new alkoxylation manufacturing plant in Pasadena, Tex. The plant's production capacity is 170,000 m.t./yr, and Oxiteno has invested around $200 million over six years in the project.

BASF to increase capacity for hexanediol at its Ludwigshafen site

September 4, 2018 —BASF SE (Ludwigshafen, Germany, www.basf.com) intends to increase the production capacity of 1,6-hexanediol (HDO) at its Ludwigshafen *Verbund* site by more than 50%. After the startup in 2021, BASF's global annual nameplate capacity of HDO will be over 70,000 m.t./yr at its production facilities in Ludwigshafen and Freeport, Tex.

Mitsui Chemicals to increase elastomers production capacity in Singapore

August 24, 2018 — Mitsui Chemicals, Inc. (Tokyo; www.mitsuichem.com) is set to raise its production capacity for high-performance elastomers at its facility on Jurong Island, Singapore. The site currently produces 200,000 m.t./yr of elastomers, and after the expansion efforts, it is expected that production capacity will rise to 225,000 m.t./yr, with startup tentatively scheduled for July 2020.

LyondellBasell breaks ground for world's largest PO/TBA plant

August 23, 2018 — LyondellBasell (Rotterdam, the Netherlands; www.lyondellbasell.com) officially broke ground on what will be the largest propylene oxide (PO) and tertiary butyl alcohol (TBA) plant ever built. The Houston-area project is estimated to cost $2.4 billion. Once in operation, the plant will produce 70,000 m.t./yr of PO and 1 million m.t./yr of TBA. Startup of the plant is planned for 2021.

Mergers & Acquisitions

Thermo Fisher to acquire bioprocessing business from BD

September 10, 2018 — Thermo Fisher Scientific Inc. (Waltham, Mass.; www.thermofisher.com) has signed a definitive agreement to acquire the Advanced Bioprocessing business of Becton,

Dickinson and Co. (BD). BD's Advanced Bioprocessing business has annualized revenue of approximately $100 million and will be integrated into Thermo Fisher's Life Sciences Solutions Segment. The acquired business provides technical services related to a variety of peptone products for biopharmaceutical applications. The transaction is expected to close in early 2019.

Honeywell acquires sulfur recovery specialist Ortloff Engineers

September 5, 2018 — Honeywell (Morris Plains, N.J.; www.honeywell.com) has acquired Ortloff Engineers, Ltd. (Midland, Tex.; www.ortloff.com), a privately held licensor and developer of specialized technologies related to natural gas processing and sulfur recovery. Ortloff will become part of Honeywell UOP's (Des Plaines, Ill.; www.uop.com) Gas Processing and Hydrogen business. Ortloff also specializes in removing sulfur from petroleum refinery feedstocks.

Covestro and LyondellBasell initiate joint project in the Netherlands

September 4, 2018 — Covestro AG (Leverkusen, Germany; www.covestro.com) and its joint venture partner LyondellBasell kicked off a large investment project at their site in Maasvlakte-Rotterdam, the Netherlands. The Circular Steam Project incorporates technology to convert the site's water-based waste into energy. The new installation will result in an estimated 140,000 m.t./yr reduction in CO_2 emissions and will also avoid the release of around 11 million kg of salt residue into surface water.

Total sells its polystyrene business in China to Ineos Styrolution

August 31, 2018 — Ineos Styrolution Group GmbH (Frankfurt am Main, Germany; www.ineos-styrolution.com) will acquire the Chinese polystyrene business of Total S.A. (Paris, France; www.total.com). The transaction includes two facilities with a production capacity of 200,000 m.t./yr each, located in Ningbo, Zhejiang Province, and in Foshan, Guangdong Province, respectively.

Evonik to divest agrochemicals site in Kansas

August 31, 2018 — Evonik Industries AG (Essen, Germany; www.evonik.com) announced the divestment of its Jayhawk site in Galena, Kansas. The site produces precursors for agrochemicals. Under a share deal, funds advised by the international investment firm Permira will acquire the site, along with its approximately 120 employees.

Atlas Copco to acquire the cryogenics business of Brooks Automation

August 28, 2018 — Atlas Copco AB (Stockholm, Sweden; www.atlascopcogroup.com) has agreed to acquire the cryogenics business of Brooks Automation, Inc. (www.brooks.com), for a total value of $675 million. The acquisition includes cryo-pump operations located in Chelmsford, Mass. and Monterrey, Mexico, as well as a network of sales and service centers and Brooks Automation's 50% share of Ulvac Cryogenics, Inc. (UCI). ■

Mary Page Bailey

Acid Recovery Becomes the Norm

As environmental and transportation regulations become more stringent around the world, treating spent acids is becoming less of an option and more of a necessity

IN BRIEF

AN EXPENSIVE NECESSITY

EACH APPLICATION IS DIFFERENT

MIXED ACIDS

SMALL-SCALE RECOVERY

REGENERATING HCL FROM PICKLING

Acids play many different roles in a large number of sectors of the chemical process industries (CPI). They are used as catalysts or as reagents in chemical synthesis; they are used for leaching metals from ores; for purifying and plating of metals and for cleaning metal surfaces. In some cases, they are also produced as byproducts, and recovered as solutions to prevent their release into the atmosphere as gases.

In the course of any of these processes, the acid becomes diluted or contaminated with impurities, or both, creating a waste stream — often in very large volumes — known as spent acid. Re-processing this waste stream is more and more becoming the responsibility of the producer.

In the past, such spent acids — depending on the contaminants — could be neutralized and discharged into wastewater treatment plants, or sold to other CPI sectors that could use the acids for purposes where the contaminants would not be problematic. Or the spent acids could be transported to toll manufacturers that specialize in treating the spent acids — removing the contaminants and recovering, purifying and re-concentrating the acid for resale.

Today, many of these options are drying up. Tighter environmental regulations are making disposal costs too high. Rules for transporting hazardous waste are making it too expensive to send spent acids elsewhere for reprocessing. Industries that were once able to use the spent acids — such as the fertilizer industry — are disappearing from areas where the spent acids are generated. "In Europe, the fertilizer industry essentially does not exist anymore," says Keith Bundil, director of Process Innovation, Pfaudler Group (Neu-Isenburg, Germany; www.pfaudler.com). As a result, "operators are left with only two choices: invest in acid recovery, or stop production," he says. Of course, they can also move production to where there are more disposal options available for spent acids, but even in countries like India and China, environmental regulations and restrictions on transporting hazardous waste are becoming stricter, says Bundil. "Therefore, concentration and regeneration of spent acids is becoming more and more important."

Jacobs

FIGURE 1. Investment in an acid regeration plant is expensive, as can be seen by the size and complexity of this typical sulfuric acid concentration plant

"Probably the major change in the last few years is the increased focus on acid recovery in Asia (especially China) and India," agrees Ken Armstrong, director of technol-

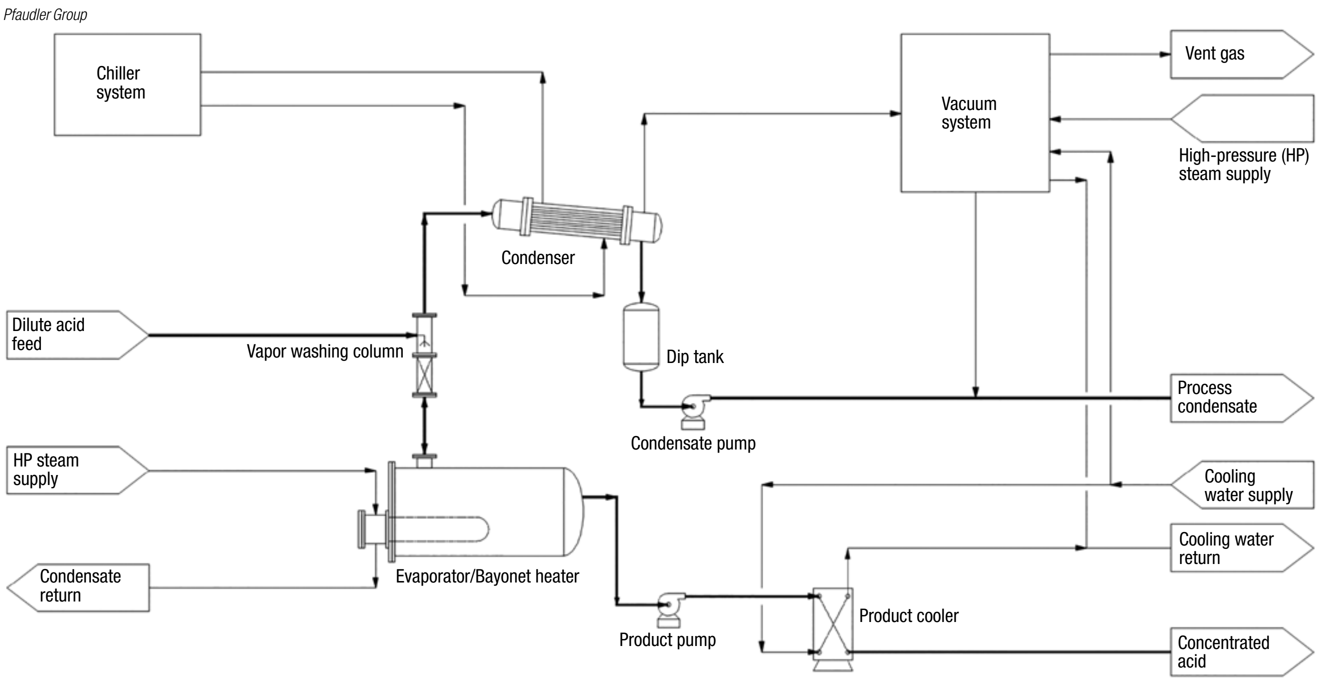

FIGURE 2. Vacuum-based processes now play a dominant role in acid-recovery processes, as seen in this typical acid-concentration system

ogy & Development at Chemetics, Inc. (a Jacobs company; Vancouver, B.C., Canada; www. jacobs.com/ chemetics). "Acid recovery is almost always based on economics: if it is cheaper to give/sell the spent acid to use for another purpose, then this is preferred. If this is not possible or allowed, then cleaning and re-concentration will be the next cheapest option. If no other alternatives exist, then companies either contract out

De Dietrich Process Systems

FIGURE 3. Glass or glass-lined steel is often the best material of construction for acid recovery plants (except for HF), as seen in this denitration column

Jacobs

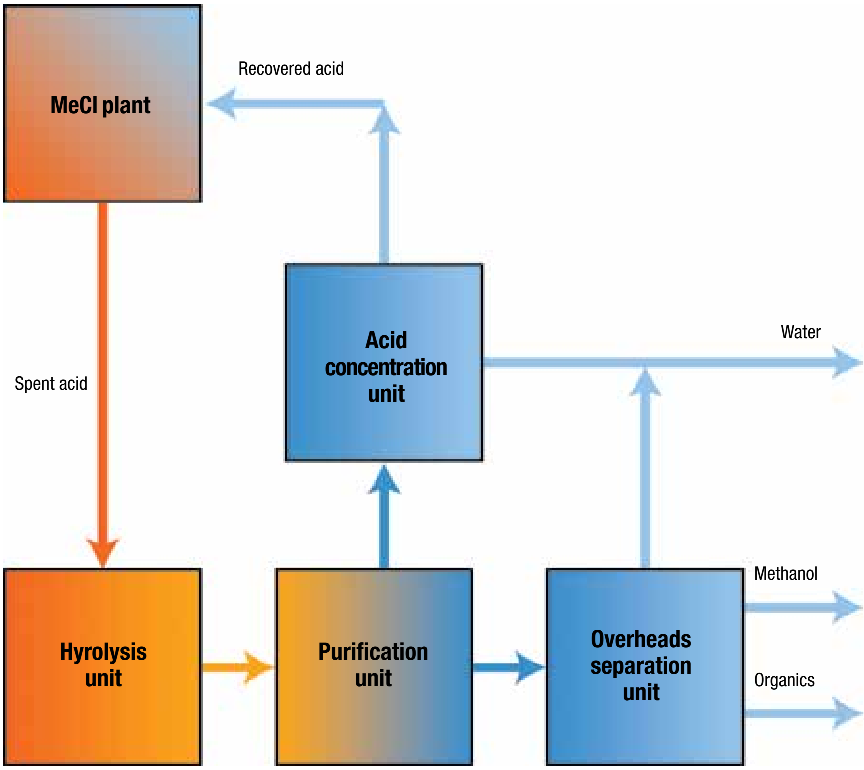

FIGURE 4. This process for treating spent acids in the production of methyl chloride first removes the organic contaminants before the H_2SO_4 is recovered and concentrated for reuse in the process

or build a thermal destruction plant to deal with the acid, such as a sulfuric acid regeneration [SAR] plant [Figure 1]. This is the most expensive solution," he says. "In Southeast Asia, we have seen more local regulatory pressures on companies to deal internally with their own spent acids and avoid sending it offsite to others to handle," explains Armstrong. "Essentially, this is just the same general global trend to reduce, reuse and recycle byproducts and wastes within your own facility."

An expensive necessity

Today, it is still extremely expensive to recover and concentrate acids, like sulfuric acid (up to 96 and even 98 wt.%), with capacities of more than 20 tons per hour, and with removal of inorganic or organic impurities. You need special materials of construction and a lot of energy, says Bundil. That means materials such as glass, glass-lined steel, tantalum and niobium — "never simple stainless steel," he says. Although the basic chemistry and physics for acid recovery are no different than they were decades ago, there have been constant evolutionary improvements in acid-recovery technology. Being more than two decades in this business, the development of more sophisticated technologies is essential, says Bundil, such as the change from atmospheric to vacuum processes (Figure 2) back in the 1980s and other efforts to reduce energy requirements, such as internal energy recovery and multi-effect evaporators.

Unlike engineering companies that design and build acid-recovery plants, Pfaudler Group provides a more holistic strategy, offering the benefit of single source responsibility for acid-recovery plants and systems, starting with the design, engineering and supply of the relevant equipment, followed by construction management, commissioning and maintenance assistance all the way until the end of the lifecycle of such a plant, says Bundil. This "one-stop" strategy includes the complete range of services and supplies, necessary for a successful implementation of an acid-recovery plant, he explains.

So, in addition to the core business of glass-lined (Glasteel) and alloy equipment, the Pfaudler Group offers several branded product lines that include Edlon, fluoropolymer-lined column and column internals; Normag, borosilicate 3.3 glass equipment and systems; Montz, engineered column systems and column internals; Mavag, specialized in drying and filtration applications; and Interseal, which includes a patented dry-run sealing technology for rotating equipment.

Each application is different

Although there are just a few important mineral acids — HCl, HF, H_2SO_4, HNO_3 — the number of different spent acids requiring treatment is much higher. Depending on the process, the spent acids are generated in different concentrations, or as mixtures of several acids, or with different contaminants. "Mixed acids are not the problem; instead, it is the accompanying impurities that make each application different," says Edgar Steffin, head of marketing, De Dietrich Process Systems GmbH (Mainz, Germany; www.dedietrich.com). Common acid mixtures are effluents from nitration processes used for making toluene diisocyanate (TDI), nitro cellulose or explosives, which contain H_2SO_4, HNO_3 (Figure 3) and organic components, he explains. For a long time, it has been possible to separate the acids from H_2SO_4/HNO_3 mixtures. Today,

Beta Control Systems

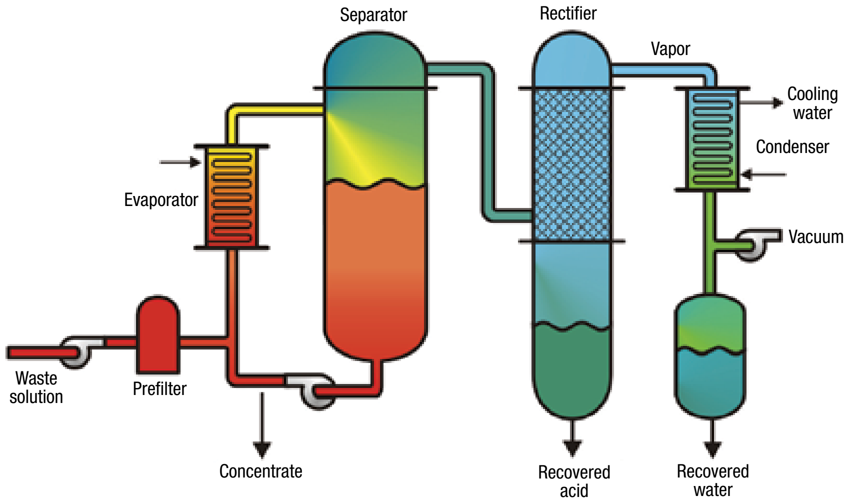

FIGURE 5. Shown here is a process for recovering mixed acids

the challenge is to do this using as little energy as possible, and to recover or get rid of the organic components, says Steffin.

Most spent-acids-concentration plants contain some novelty to handle the impurities in the acid, concurs Chemetics' Armstrong. "The acid-concentration part is never the challenging aspect of the project. Dealing with the impurities in the spent acid is always a challenge, and can be the difference between an easy, cheap solution and an expensive one," he says. For example, a major process Chemetics has developed in recent years is one to purify and recycle methyl chloride spent acids. "This process was custom developed for a client and is now in operation in three locations," says Armstrong.

In the production of methyl chloride, concentrated H_2SO_4 is used to remove impurities — mainly dimethyl ether, which is formed as a byproduct, and unreacted methanol — from the methyl chloride vapor stream exiting the reactor. The spent acid leaving the plant also has small amounts of methyl chloride.

The success of the recycling of this waste stream depends on the effective removal of the contaminants, says Armstrong. Methanol reacts with H_2SO_4 to form methyl sulfuric acid, which is difficult to remove from spent acid, so the first step is to "liberate" the methanol and recover the H_2SO_4 in the hydrolysis unit. The second step then removes the organic contaminants from the acid, which eliminates problems in the downstream acid concentration. The process is said to offer "virtually complete" removal of contaminants — more than 99% recovery of sulfuric acid for recycle to the methyl chloride plant, and more than 70%


Mech-Chem Associates

Figure 6. For small-scale operations, such as aluminum anodizing, sulfuric acid can be recovered by diffusion dialysis in modular membrane-based systems

recovery of methanol for recycle, according to the company.

Mixed acids

Mixed acid recovery has been the biggest change in applied acid recovery technology, says Bryan Cullivan, president of Beta Control Systems, Inc. (Beaverton, Ore.; www.betacontrol.com). Whether HNO_3/HF or HCl/HF, the cost of the acid and the cost of disposal have opened a marketplace for acid recovery that the cheaper HCl and H_2SO_4 markets did not enjoy, he says. "We recently introduced the Mixed Acid Recovery System into the aerospace and stainless steel markets to compete with acid retardation. The capital return is much quicker for the more expensive acids," he says. "Using vacuum evaporation coupled with a forced circulation co-flash approach, we were able to provide excellent recovery of HF, HNO_3 and HCl in a relatively compact design. As a result of the extreme corrosiveness of the acids, all of the components in the process had to withstand both the temperature and the aggressive environment to be practical. The patent process is underway and so far, the first applications continue to perform," he says.

In the mixed-acid recovery process (Figure 5), a waste acid is pumped through a pre-filter and into the evaporator loop, comprised of an evaporator exchanger and a separator tank. In the evaporator loop, spent acid is pumped under slight pressure through a corrosion-proof heat exchanger. The spent acid solution is heated past the boiling temperature of both acid and water. "Once the solution is released into a controlled vacuum environment, both the mixed acid and water vaporize in our unique 'co-flash' reactor," he explains. The acid and water vapors travel upward through the liquid/vapor separator tank and into the rectifier. The remaining metal salt solution (metals + H_2O) continues to circulate through the pressurized boiling loop until it reaches a specific concentration and is discharged to a storage tank.

In the rectifier, the concentration of acid is controlled to return excellent quality, re-concentrated acid to the process tank. The remaining water vapor, stripped of HNO_3 and HF, continues into the condenser where it is sub-cooled and condensed to good quality water. This water is typically reused in the process.

One of the company's most recent projects has been the recovery of HF and HNO_3 from titanium milling. "The separated product was not only the high-valued acid, but also the recycled titanium," says Cullivan. He also points out that Beta installed the largest sulfuric acid recovery system in North America two years ago. The system is essentially two systems with a common walkway and has a processing capacity of 32,000 gal/d of spent acid.

Small-scale plants

Whereas large-scale acid recovery plants continue to be thermal-based processes, smaller systems based on acid dialysis have been developed by Mech-Chem Associates, Inc. (Norfolk, Mass.; www.mech-chem.com). These compact modular units are ideally suited for recycling sulfuric acid used in aluminum anodizers and the metal plating industries, says marketing manager Ian Butler. "These systems have demonstrated improved anodize quality, producing consistent anodize color and consistent anodize thickness, while reducing bath dumping and makeup," he says. The modular, compact units (Figure 6) can be adapted to handle the production volume requirements of a given application, with commercial modules handling capacities of 15 to 1,000 gal/d. Larger capacities are realized by adding membrane modules in parallel. A laboratory unit is also available for evaluation purposes, and the data gathered are used for scaling up to pilot or full-scale installation at a facility.

The systems are based on a membrane-separation process known as diffusion dialysis. Two feed streams flow countercurrent between an anion-exchange membrane, which acts like a semipermeable barrier between the water stream and the acid stream (which contains the dissolved metals). Driven by a concentration gradient, the acid permeates through the membrane into the water stream, while the metal ions are rejected by the membrane, thereby creating a purified sulfuric acid solution. The system can remove and control other contaminant build-ups in the anodized bath, such as copper, iron, lead, magnesium, manganese, phosphate, silicon and zinc, while producing a minimum of rejected waste byproduct for subsequent treatment and disposal, says Butler. Typically, 80–95% of the acid is recovered with 80–95% of the metals removed, on a single pass-through, according to the company.

In addition to dialysis technology, Mech-Chem provides large-scale thermal-separation technology for acid recovery. For example, the company is currently involved in acid purification, using distillation/fractionations, of electronic-grade HF, HNO_3, and H_2SO_4, says Butler.

Regenerating HCl from pickling

Hydrochloric acid is commonly used in the pickling lines of steelmaking, a cleaning process that generates large volumes of acidic rinse water, iron chlorides, metallic salts and waste acid. For such large-scale operations, it may make more sense to regenerate the acid from the iron chlorides, rather than recovering the spent acid. For the HCl regeneration, two main processes are used: fluidized-bed (FB) and spray roaster technologies, says Herbert Klausner, senior technologist at Tenova Key Technologies Industriebau GmbH (Vienna, Austria; www.tenova.com). Although the company offers both, the market is moving more towards the spray roaster technology, mainly driven by economical aspects, he says. Spray roasters operate at a temperature of around 640°C, compared to 950°C for FB, for example.

In the process, waste acid is preconcentrated, then pumped to the roaster, where it is injected. The liquids are circulated in a venturi, and the ferric and ferrous chlorides are roasted into iron oxide pellets, with the release of HCl. The solids are recovered at the bottom, and the HCl gas recoverd in an absorber column as nealry azeotropic hydrochloric acid (about 18 % by weight). The regenerated acid can then be stored and reused in the pickling plant.

In recent years, Tenova has improved its Spray Roaster technology, with a significant enhancement of operating costs, product quality and environmental protection. Under the BLUEdriven trademark, the most recent innovation has been the BLUEdriven Flex Capacity, which makes it possible to cover a very wide plant capacity. If the capacity of the pickling plant is increased, the regeneration capacity can be added in parallel to the existing acid-regeneration plant in just a week or two, without exchanging equipment. This enables small-scale or startup companies to have a mid-term investment schedule, with the ability to increase capacity to 100% at a later time. Also, the metal-oxide pellets that are formed from the pickling sludge can be fed directly into the blast furnace, without the need for sintering (a process that operates at 1,300°C). The hardening process does not require an oven, says Klausner.

The first plant with BLUEdriven Flex Capacity started operating this summer, and a second plant with the same characteristics will start up at the end of 2018.

In addition to its activities in the steelmaking industry, Tenova is also seeing interest in acid recovery for the titanium and magnesium industries. The company is also working on new applications for regenerating organic acids from the production of biodegradable plastics. This development could also be used in many areas of the food industries, Klausner says. The process is being developed in a pilot plant. ■

Gerald Ondrey

Sealing the Deal

Increased reliability, chemical compatibility and containment of sealing solutions are priorities for chemical processors

IN BRIEF

COMPATIBILITY CONCERNS

HIGH TEMPERATURES AND PRESSURES

CONTROLLING LEAKS

IMPROVING RELIABILITY

Seals and gaskets may seem like an afterthought in the grand scheme of chemical processing equipment, but if you've ever been faced with unexpected — and costly — downtime due to a seal or gasket failure, you know these products are as crucial to the process as their larger-scale counterparts. As the chemical process industries (CPI) continue to demand better chemical, pressure and temperature compatibility, tighter emission control and higher reliability from their seals and gaskets, new solutions are being explored.

American High Performance Seals

FIGURE 1. **When it comes to compatibility, it is essential that the sealing material is compatible not just with individual chemicals, but with the product that results from mixing those chemicals.**

"Everyone believes a seal is a seal is a seal and it is not going to be a problem until it becomes a problem," says Derek Duncan, technical director with American High Performance Seals, Inc. (Oakdale, Pa.; www.ahpseals.com). This, he says, is especially true in the CPI where chemical compatibility, special sanitary needs and high pressures and temperatures are issues and high value processes and products demand reliable sealing solutions. "These concerns often dictate the use of high-performance products."

Compatibility concerns

While it is not difficult to select a compatible sealing material for a single chemical, one of the biggest areas of concern in the CPI, says Duncan, is chemical compatibility when mixtures are involved. "We often have processors come to us with a list of five or six different chemicals they run and want to know what seal material is compatible with those chemicals," he explains. "What they don't realize is, that once in process, the seals aren't seeing those chemicals individually, but rather as a combination and the seal material may not be compatible with the results of the process," he says (Figure 1).

For example, "I have seals that are compatible with water and seals that are compatible with glycol, but those same seals would not be compatible with a water/glycol combination." In many cases, he says, these situations can be resolved by running a compatibility test. "It is possible that a processor could get three to four times the life for half the cost if they were to work with a seal manufacturer with compatibility test capabilities," says Duncan.

How the equipment will be cleaned can also have an impact on seal design. "It is not uncommon to discover that the best seal design and material for the application are totally unsuitable for the intended cleaning method," says Duncan. "Seals are designed for the chemicals they are pumping, so if there is a clean-in-place, steam-in-place or autoclaving cleaning service, that needs to be addressed during seal design and selection. Often these cleaning processes cook the seal, drastically reducing reliability of the seal, so it's a very important detail to mention upfront."

Also in sanitary environments where U.S. Food and Drug Administration (FDA; Silver Spring, Md.; www.fda.gov) seals are needed it's necessary to look beyond the FDA-ap-

Trelleborg

FIGURE 2. Isolast J9567 is a technically advanced multi-purpose FFKM that offers broad chemical and temperature resistance to provide cost savings to a variety of applications within downstream hydrocarbon refining

Technetics

FIGURE 3. The Helicoflex is a spring-energized metal seal with metal cladding on the outside. Its materials and design make it very suitable for high temperatures and pressures in the chemical industry

proved seal materials and consider the design, as well, says Duncan. "Processors often ask for an FDA-approved seal material, but this necessitates more than a standard seal design in an FDA-compliant material. Many FDA materials have fitment issues, as they sometimes require an open housing that will either be damaged or impossible to fit in a closed gland. The direction of insertion of the seal into the housing and shaft through the seal can also present challenges. For this reason, it is recommended that general assembly drawings be presented to the seal manufacturer as early as possible to overcome these issues."

In addition, FDA seals for the food industry use many housing, piston and shaft materials that present challenges to seal design. "For example," says Duncan, "Counter surface materials can drastically reduce the possible seal materials available to the designer. An aluminum housing necessitates a different material than a stainless-steel housing does."

High temperatures & pressures

In the CPI, it is not uncommon to increase temperatures and pressures in an effort to boost throughput. However, this can have an impact on seals and gaskets. "Many processors are finding that seal materials are the limiting technology preventing them from increasing temperatures," says Colin Macqueen, director, R&D, Trelleborg Sealing Solutions Americas (Fort Wayne, Ind.; www.trelleborg.com). "For increasing pressures it is important to work with a seal supplier who can offer a full portfolio of products and applications expertise to avoid a sub-optimal solution from a limited offering."

He continues: "If a custom sealing solution is required, it is important for the equipment manufacturer to understand the specific application requirements, which include not only temperatures and pressures, but many other factors including dimensional tolerances. Withstanding high pressure is often a matter of tolerancing so that the maximum gap to be sealed can be well understood at the design stage."

Macqueen points to Trelleborg's Isolast perfluorelastomer (FFKM) as a development intended to provide better choices for chemical compatibility, mechanical properties and temperature resistance. He says, "Isolast J9538 offers the mechanical properties to optimize production, the thermal and chemical stability to resist clean-in-place and sterilize-in-place and water-for-injection regimes, and is compliant with or is certified to FDA, 3-A and USP [U.S. Pharmacopeia] standards. This profile of attributes improves performance in applications such as mix-proof valves, mixers, pump and centrifuges for pharmaceutical, healthcare and medical industries."

In addition, Isolast J9570 offers low temperature performance down to –40°C while maintaining chemical resistance, making it suitable for sub-zero environments, such as couplings when transporting aggressive chemicals and downstream petrochemical and refinery equipment. And Isolast J9567 (Figure 2) is a technically advanced multi-purpose FFKM (a perfluoroelastomer) that offers broad chemical and temperature resistance to provide cost savings to a variety of applications within downstream hydrocarbon refining.

Thermal cycling is often a problem in high temperature operations, as well, notes Ron Frisard, field product manager, stationary sealing, with A.W. Chesterton (Groveland, Mass.; www.chesterton.com). To help compensate for this, the company offers its valve cartridge live-loading technology for difficult valves at high temperatures that are subject to a lot of thermal cycling, such as those in nuclear and fossil power, petroleum refining, petrochemical and chemical industries. "The live loading technology compensates for a variety of system conditions and optimizes reliable valve sealing by maintaining a consistent load on the packing gland," he says. "You can minimize valve-induced process fluctuation and reduce associated leakage due to system disturbances, such as thermal expansion and contraction, improving equipment uptime."

Higher temperatures and pressures also drive the need for metal seals, says Ryan McCall, product manager for high performance metal seals with Technetics (Columbia, S.C.; www.technetics.com). One of the company's main products, the Helicoflex (Figure 3), is a spring-energized metal seal with metal cladding on the outside. "Its materials and design make it very suitable for high temperatures and pressures in the chemical industry because the spring-energized core provides elasticity to help maintain a specific pressure, while the outer cladding is compatible with many chemistries," says McCall.

The sealing principle of these seals is based upon the plastic deformation of a jacket of greater ductility than the flange materials. This occurs between the sealing face of a flange and an elastic core composed of a close-wound helical spring. The spring is selected to have a specific compression resistance. During compression, the resulting specific pressure forces

the jacket to yield and fill the flange imperfections while ensuring positive contact with the flange sealing faces. Each coil of the helical spring acts independently and allows the seal to conform to surface irregularities on the flange surface.

Controlling leaks

Metal seals, says Jonathan Kweder, product manager, aerospace, with Technetics, are also suitable for controlling emissions. "A metal seal that is sealing properly will allow you to start reaching very low leak rates," he says. In addition, metal seals are typically not as permeable as other seals, so the gas or fluid will not be able to permeate through the seal itself, which means outgassing is not a concern.

Emissions are a particular problem for valves in the chemical industry, so Chesterton 1726 Low E Packing (Figure 4) was designed to meet new reduced emission levels without live loading. The packing is constructed with a combination of polytetrafluoroethylene (PTFE) surrounding a carbon core in a true double-braided formation. The PTFE jacket provides chemical resistance and lower friction while the specially formulated carbon core provides sealing capability in harsh, corrosive environments. The result is a non-hardening, flexible packing that is strong, yet extrusion resistant for a secure and reliable seal for emissions service.

A.W. Chesterton

FIGURE 4. Chesterton 1726 Low E Packing was designed to meet new reduced emission levels without live loading. The packing is constructed with a combination of PTFE surrounding a carbon core in a true double-braided formation

Thordon SeaThigor

FIGURE 5. The Thordon SeaThigor is a mechanical face seal for water-lubricated propeller shafts that has been manufactured for long wear life and low maintenance costs, has no visible leakage and offers metal compression springs used to maintain constant face closing forces

In marine vessel applications, leakage of environmentally accepted lubricants (EALs) used to lubricate the propeller shaft is also a problem

because oil-based EALs need to be compatible with the sealing materials to ensure that leakage is controlled, says Terry McGowan, president and CEO of Thordon Bearings (Burlington, Ont., Canada; www.thordonbearings.com). "Oil-based EALs may impact the seal wear life, meaning increased maintenance costs, as these lubricants are three to five times more expensive than mineral oils, and they are still considered a pollutant so leaks must be reported and cleaned up, so we needed a solution," he says. So, his company developed a system that uses water lubrication. The Thordon SeaThigor (Figure 5) is a mechanical face seal for water-lubricated propeller shafts that has been manufactured for long wear life and reduced maintenance costs, has no visible leakage and offers metal compression springs used to maintain constant face closing forces. The seal is designed so that the pressurized water is placed on the outside of the sealing rings, using water pressure to keep the faces closed. This is particularly important for deep-water operation when there are pressure fluctuations that can open the faces of traditional seals, causing leaks. The SeaThigor uses a balanced design with an optimal balance ratio that enhances operation stability when subjected to fluctuation of water pressure.

A.W. Chesterton

FIGURE 6. The 442C cartridge split seal addresses the inherent limitations found in conventional cartridge split seal designs by offering easy installation and replacement without the need for teardowns

Improving reliability

One of the biggest issues associated with reliability in mechanical sealing systems is the maintenance aspect, so seal manufacturers are looking to help increase reliability via improved designs. "What we are seeing is processors working with smaller maintenance teams that are typically expected to complete the same amount of work with less manpower," says Steven Bullen, global product line manager, mechanical seals, with A.W. Chesterton. "So, we've been working to simplify the mechanical seals and sealing systems and develop solutions that are intrinsically reliable. We engineer the seal to perform in applications without the need for external support, which provides two benefits: It lowers the initial acquisition and maintenance costs because users are only looking after the seal, not the support system and, at the same time, it removes the risk of operator or maintenance error during installation or repair."

He continues: "If someone adjusts a sealing system in the wrong way, it can result in failure, so by eliminating the need for a piece of external equipment, we can increase reliability and reduce the operating cost of equipment while increasing the profitability of our customers."

Some examples of their user-friendly mechanical seal designs include the Chesterton 442 split seal and 442C cartridge split seal. The 442 split seal is designed for equipment that is difficult and time consuming to disassemble, such as large pumps, vertical pumps and horizontal split case pumps. It was designed with the installer in mind so the ball-and-socket O-rings provide a quick and easy leak-free seal without the use of adhesives, the captive screws cannot fall out, making installation straightforward and reliable, and the compact design allows for easy installation and a fit advantage on most equipment. The 442C cartridge split seal (Figure 6) combines performance with ease of installation. The split seal technology addresses the inherent limitations found in conventional cartridge split seal designs by offering easy installation and replacement without the need for teardowns.

"This line of split seals was designed for larger equipment and gives the advantages of putting on a replacement seal without having to take the equipment out of service, so it can be done while the piping and motor are still connected," says Nicholas Sirois, global product manager, mechanical seals, with A.W. Chesterton. "It is truly a replace-in-place solution." ■

Joy Le Pree

Focus on Valves

These versatile, modular valves enable quick installation

More than 2,500 configurations are available in the the Spira-trol Control Valve family (photo). These modular valves are pre-commissioned in the manufacturer's U.S. factory, and are shipped within two to three days of the order, allowing for immediate "plug-and-play" installation, says the company. The modular design, with a quick-change, self-aligning "clamp-in-place" seat, allows the valve's duty to be altered to match changing plant conditions (rather than requiring a replacement valve). The valves offer simplified maintenance, as no special tools are required. Many conventional valve designs have screw-in seats that can seize in place, requiring shutdown for valve removal. Electrically and pneumatically actuated designs are available. The product range extends up to 8 in. and ANSI 600 pressure envelope.— *Spirax Sarco USA, Blythewood, S.C.*
www.spiraxsarco.com

This valve is suitable for use in pharma-grade water systems

The DV-ST Ultra-Pure Valve (photo) is designed to meet the demands of pharmaceutical-grade, purified-water systems. This compact, lightweight diaphragm valve is modular in design, which enables its use in a diverse array of purpose-built configurations, to control and maintain water quality, flow and temperature in the distribution loop during pharmaceutical manufacturing. This valve has low specified sulfur content (which enables superior weld quality), and its stainless-steel valve body has low delta-ferrite content, says the company. It also has a relatively low weight, which reduces the stress on the piping. — *Alfa Laval Kolding A/S, Kolding, Denmark*
www.alfalaval.com

Protect drilling pipelines from overpressure

The CRV26 pressure-relief valve (PRV; photo) is engineered to protect drilling systems, used for petroleum recovery, from overpressurization. It is the first of its kind to be rated for 10,000-psi systems, according to the company. The CRV26 PRV is suitable for frelief in hydraulic fracturing systems, mud-pump relief and managed-pressure drilling, and it is compatible with API 6A and NACE MR0175 requirements, according to its manufacturer. — *Cortec, Fluid Control Div., Houma, La.*
www.uscortec.com

Cut VOC losses from tanks by maintaining constant pressure

Minimizing emissions of volatile organic compounds (VOCs) from oil tankers in transit is challenging because of fluctuating ambient conditions experienced during sea voyages. Controlled release of VOCs is often undertaken when the gas pressure in the tank approaches a pre-set threshold. The Vocon Valve and Reporting System (photo) controls the vapor pressure inside oil cargo tanks to minimize and control VOC emissions. The system, which combines a venting control valve operated by an electric process valve actuator, is installed on the bypass line between the inerting gas pipeline and the mast riser. In automatic mode, the actuator modulates the valve position in response to a control signal from a pressure transmitter, to control the vapor pressure in the cargo tanks. It complies with the latest international rules and regulations, and has an advanced reporting system, according to the manufacturer. Its wide ambient operating temperature range (from –20 to 65°C) makes the system versatile in the exposed conditions experienced by oil tankers at sea. — *Rotork PLC, Bath, U.K.*
www.rotork.com

These safety valves handle diverse liquids and gases

This company offers a large array of safety valves for many chemical process industries (CPI) applications. These include valves for pressure-loaded systems (handling

Spirax Sarco

Alfa Laval

Cortec

Rotork

Note: For more information, circle the 3-digit number on p. 74, or use the website designation.

Eisele Pneumatics GmbH

DunAn Microstaq

Müller GmbH

Asahi/America

pressures to 550 bars), valves for the storage and transport of cryogenic gases and liquefied natural gas (handling temperatures as low as –269°C), and valves that can withstand damage from media (such as seawater and chemicals) in severe process environments. The company's large portfolio of highly engineered safety valves are available for steam service, pneumatic conveying applications, systems handling compressed air, chemicals and fuels and more. — *Herose GmbH, Oldsloe, Germany*
www.herose.com

Improve compressed-air safety with these check valves

This company has expanded its Basicline Series 25 with pilot-operated check valves for compressed air (photo). These nickel-plated-brass valves can be used in combination with pneumatic cylinders in a variety of industrial and medical applications to prevent injury and equipment damage in the event of sudden pressure drop in pneumatic cylinders. The pilot-operated check valves enable flow in one direction, which in return, blocks flow in the opposite direction, thereby preventing pneumatic cylinders from unintentionally deaerating in the event of a pressure drop. This valve is designed for a working pressure range of 1 to 10 bar, and a temperature range of –10 to 70°C. As an additional connection supplement, the company also offers a swivel joint in Series 25, which can be activated through compressed air or it can be used with manual activation. — *Eisele Pneumatics GmbH, Waiblingen, Germany*
www.eisele.eu

Silicon valve supports heating and cooling operations

The Very High Capacity Modular Silicon Expansion Valve expansion valve (VHC-MSEV; photo) is available for the 25–50-ton heating, ventilation and air conditioning (HVAC) and refrigeration market. This family of valves expands the cooling capacity range of the MSEV product line from the existing 1–25-ton range to 25–50 tons. This valve package has a preset library of refrigerants, including A2L refrigerants, within its controller, and it can be adapted to new or application-specific refrigerants. This, combined with its modular design, allows it to support various applications at different cooling capacities within a single footprint, says the company. — *DunAn Microstaq, Austin, Tex.*
www.dmq-us.com

Single-use split butterfly valve provides reliable containment

This company has introduced an automatable, single-use variant of its well-established stainless-steel Müller Containment Valve (MCV). The single-use version, called the MSV-LW (photo) for its lightweight construction. It is manufactured from a performance polymer to reduce cost and weight. The levers for locking the valve and actuating it can easily be changed over from those used for manual operation and those for pneumatic actuation. The pneumatic actuators can be controlled via a programmable logic controller (PLC). The single-use valve is designed for GMP-compliant manufacturing where powders and granular materials are processed, reducing the risk of cross-contamination. Its modular design concept enables pneumatic actuators, position sensors and even lifting devices for automated docking and undocking to be integrated. — *Müller GmbH, Rheinfelden, Germany*
www.muellerprocessing.com

Redesigned butterfly valve comes in a variety of polymers

Extending its existing Type-57 family of butterfly valves, the new Type-57P butterfly valve (photo) has been redesigned with an ANSI wafer-style connection. This new valve shares the same face-to-face dimensions as all similarly sized Type-57 butterfly valves. New features of the Type-57P include two molded tag holes in the valve body for user-defined valve identification, and a highly visible throttle-positioning plate. The plate, which features an opening degree legend in 10-deg increments, makes accurate throttle positioning between zero deg (closed) and 90 deg (open) possible. The Type-57P's body and disc are injection-molded for durability, and the 316 stainless-steel stem is

non-wetted. A variety of sizes and materials are available (including polyvinyl chloride, chlorinated polyvinyl chloride, polypropylene and polyvinylidene fluoride), and all sizes can be electrically or pneumatically actuated. — *Asahi/America, Lawrence, Mass.*
www.asahi-america.com

Rotary valve ensures smooth delivery of bulk solids


Coperion K-Tron

The ZRD rotary valve (photo), designed for discharging and metering powders and granular solids during conveying, is the newest member of the company's Aerolock family of rotary valves. It is specially designed for food, mineral, plastics and chemical applications. The valve is engineered for heavy-duty industrial service with pressure differentials up to 21 psig (1.5 barg) and temperatures up to 212°F (100°C), and higher-temperature options are available. An extensive range of sizes is available, with large throughputs from 500 to 400,000 lb/h). The valves have a pressure-surge-proof (pressure-shock) rating up to 145 psig (10 barg), and are suitable for isolation according to NFPA standards (for select sizes up to 12 in.). — *Coperion K-Tron, Salina, Kan.*
www.coperion.com

Check valve design promotes smooth water flow


Val-Matic Valve & Manufacturing

The Swing Check Valve (photo) has rugged construction and full flow area for industrial and municipal water and wastewater applications. Its smooth, unrestricted design can provide significant savings in pumping costs over other check valves with reduced ports. Several closure options are available, including Lever and Weight, Air Cushion, and Lever and Spring, allow the valve to be used effectively in a wide range of pumping system applications. Metal-to-metal seating is also available with reliable operation under harsh conditions. These valves are designed, built and tested for compliance with ANSI/AWWA C508, NSF/ANSI 61, NSF/ANSI 372, and MSS SP-71/MSS-SP-136, according to the company. — *Val-Matic Valve & Manufacturing Corp., Elmhurst, Ill.*
www.valmatic.com

This diverter valve supports pneumatic conveying of solids


Schenck Process

The PST30 Diverter Valve (photo) introduces new features, such as internally shimable positive stops, inflatable pneumatic seals at each port, position indication from the tunnel itself, and external tunnel position indication. Addition features include 145-deg port-to-port rotation, a two-way switching capability for either dilute-phase or dense-phase conveying applications, aluminum or Type 316 stainless-steel housing, end plates, plugs and inlet and outlet ports flanged to mate 150# ANSI or 10N-DIN flange patterns. To complete the unit, a pneumatic actuator providing a 4-s actuation time between ports, a four-way double and three-way single solenoid air control valve with NEMA 4 enclosure, and two proximity sensors, are included. — *Schenck Process LLC, Whitewater, Wis.*
www.schenckprocess.com

This ball valve is designed to save labor and downtime


Conval

The Camseal metal-seated, severe-service, forged ball valves (photo) feature zero body, seat and stem leakage on standalone and actuated valves, ensuring reliable, long operating life, according to the manufacturer. This valve is available in sizes

AS-Schneider

NewTek Sensor Solutions

Emerson

IEP Technologies

from 0.5 through 4 in., with socket-weld, butt-weld and flanged ends, in pressure classes through ASME 4500#. The top-entry, cartridge-style ball valves are said to be easy to inspect, maintain and repair. The cartridge can be conveniently removed for onsite parts replacement, reassembly and reinstallation. No welding is required. The valve is available in a variety of materials. — *Conval, Enfield, Conn.*
www.conval.com

Improved ball valve design reduces torque

Process plants handling abrasive materials, especially at high temperatures and high pressures, often need metal-seated ball valves, and extreme operating conditions with temperatures to 450°C and pressures to 420 bars require special sealing technology for ball valves that are more rugged than standard soft-seated ball valves. The patented Dissolution ball valve design (photo, p. 34) offers optimum distribution of forces and loads in the ball valve, allowing it to be actuated easily even at pressures to 420 bars, says the manufacturer. The seat and ball surfaces are coated with Hardalloy and carbide compounds at the metal seated ball valve. During operation, the forces needed to maintain the tightness between the ball seat and the valve body are only directed onto the corresponding graphite seal rings. The ball is spring-loaded, which ensures a low, defined minimum pressure and smooth, reliable operation — *AS-Schneider, Nordheim, Germany*
www.as-schneider.com

Miniaturized position sensor can handle harsh conditions

The M-375 Series Miniature AC LVDT (photo) is an a.c.-operated position sensor for applications with harsh and high-pressure environments with limited space. It is lightweight and has a compact 3/8-in. dia. It has a corrosion-resistant, nickel-iron alloy housing and core, and operates in temperature extremes of –65° to 400°F, to provide reliable, linear position feedback in harsh and high-pressure industrial applications with tight space and weight restrictions. It provides high-response dynamic measurement for machine operations, such as robotics, automatic inspection equipment, plastic injection molding, hydraulic cylinder and valve positioning, downhole drilling and dimensional gaging, says the company. The LVDTs in this product family are available in many measurement ranges. — *NewTek Sensor Solutions, Pennsauken, N.J.*
www.newteksensors.com

Ultrabright valve-position indicator boosts plant safety

The TopWorx TV-LED Switchbox (photo) features an ultra-bright, easty-to-see light-emitting diode (LED) visible position indicator. Visible at long distances, the position indicator communicates valve position remotely to the control room or plant personnel, to improve safey at the facility. The device can be ordered for monitor-only applications, or integrated with a solenoid valve for on/off valve control. — *Emerson, St. Louis, Mo.*
www.emerson.com

Explosion-isolation flap valves provide explosion protection

The self-actuating IFV and IFV-M Isolation Flap Valves (photo) mitigate the risk of fire and dust explosions, keeping flames and explosions from propagating to upstream equipment linked by ductwork. An isolation flap valve installed in the duct is closed rapidly by the pressure wave from the downstream explosion, ahead of the flame-front arrival. By stopping the flame from reaching the upstream vessel, it prevents the flame and explosion pressure from reaching attached vessels and creating a secondary and often more energetic explosion, says the manufacturer. The IFV-M model adds integrated monitoring of the flap position and dust accumulation in the valve body, meeting the requirements of the OSHA Combustible Dust Directive, NFPA 654 and NFPA 69. These valves are available in a variety of sizes for dust class ST1 and ST2. — *IEP Technologies, part of Hoerbiger Wien GmbH, Vienna, Va.*
www.hoerbiger.com ■

Suzanne Shelley

National Oilwell Varco

Almatec Maschinenbau

SPX Cooling Technologies

Ashcroft

This agitator avoids fibrous buildup

The Chemineer RL-3 impeller (photo) has been specifically engineered to prevent fibrous material buildup on the rotating impeller. This rag-shedding impeller also provides a strong axial flow for efficient blending and solids suspension. The design allows for a safer process and lower maintenance costs by eliminating frequent handling of the agitator by maintenance personnel, says the manufacturer. Fibrous material handling and disposal are also eliminated, improving solids suspension and blending uniformity in the basin. The loads on agitator system components, such as gears, bearings, motor, shaft and impeller blades, are significantly diminished. These features work together to not only reduce downtime, but eliminate manual process changes. Impeller sizes range from laboratory-scale to over 200 in. in diameter. Existing agitators can be quickly and easily retrofitted with the RL-3 impeller using simple hub-to-shaft connections. — *National Oilwell Varco, Houston*
www.nov.com

These AODD pumps have a safety-enhancing design

New C-Series air-operated double-diaphragm (AODD) pumps (photo) are designed to enable the housing parts to be tightened to each other via housing bolts. Rather than using single bolts that press against the housing, all of the C-Series' bolts are tightened together against a diaphragm-sized ring on each side of the pump. This design distributes the forces of the housing bolts onto the housing parts evenly, providing a consistent flow of forces that increases bolt torque and improves pump safety. The design of C-Series pumps also ensures the suction and discharge ports are available as separate housing parts so that different connection versions are available for compatibility with existing installations. In addition, these pumps provide good suction head, and feature self-priming and dry-run capabilities. The C-Series also features no mechanical seals, drives or rotating parts that cause wear over time. C-Series pumps are available in three pump sizes and achieve flowrates ranging from from 1.3 to 7 m^3/h at a maximum discharge pressure of 7 bars (100 psig). — *Almatec Maschinenbau GmbH, Kamp-Lintfort, Germany*
www.almatec.de

A solution to optimize motor performance in cooling towers

Series M Geareducers (photo) are designed and manufactured to directly replace other gearboxes in field-erected cooling towers. The Geareducer's primary function is to reduce the speed of the electric motor to optimize fan performance by maximizing air movement through the cooling tower and minimizing maintenance requirements. It provides primary support to the fan, anchors it against lateral movement, withstands shock loads at startup and during speed changes, and minimizes power-transmission losses and noise generation. The M Series features gears of case-hardened alloy steel. To further extend service life, the Geareducer is fitted with large oil passageways to help maintain lower oil temperatures. The Geareducer operates without the need for oil pumps, oil filters or oil coolers. It runs with two-stage gear reduction for efficient power transmission, and the external cooling fins maximize surface area for cooler operation. — *SPX Cooling Technologies, Inc., Overland Park, Kan.*
www.spxcooling.com

A pressure gage for frigid conditions

The T6500 pressure gage (photo) is designed for use in environments with extremely low temperatures. The 100-mm solid-front stainless-steel pressure gage features several design considerations to optimize its configuration for extreme conditions. The XQC option includes a low-temperature-rated silicone fill material that prevents ice buildup inside the gage and remains liquid at temperatures down to –94°F (–70°C). Special fluorosilicone elastomer seals deter embrittlement in extreme cold to prevent leakage. The Plus Performance option for the T6500 dampens vibration, shock and pulsation effects. — *Ashcroft Inc., Stratford, Conn.*
www.ashcroft.com

Sight-glass-mounted camera enables remote vessel inspection


Larson Electronics

The EXPCMR-IP-POE-4MP-IR-SGM explosion-proof camera (photo) is a remote inspection device specifically designed for observation in hazardous locations. Operated remotely from a centralized control room, the camera's image sensor is suitable for sight-glass applications and provides live feed from inside tanks, reactors and other vessels. This network camera features an 83-deg, wide-angle fixed lens and an integrated infrared LED array, providing low light and nighttime visibility up to 45 ft. Additionally, the remote inspection camera is built to withstand demanding conditions in explosive environments. For sight glass or surface mounting, the device can be attached directly using a nut, flanged adapter collar or hinged bracket. Bracket components allow robust, angled positioning of the light head. — *Larson Electronics LLC, Kemp Tex.*
www.larsonelectronics.com

This discharging system has built-in bag-piercing knives


Material Transfer & Storage

The patented Material Master bulk-bag discharging system (photo) includes bag-piercing knives for the discharge of materials from bulk bags with or without an outlet spout. The system utilizes a two-ton chain hoist to lift the bulk bag into the carbon-steel discharge hopper where a static two-angle bag-piercing knife assembly empties bulk bags for a complete and efficient discharge of materials. For dust control, the hopper features a full-perimeter dust plenum with a dust takeoff stub. The system is also equipped with a rigid screw conveyor to transfer materials into users' existing processes. A stainless-steel load-cell package provides loss-in-weight weighing capabilities. — *Material Transfer & Storage Inc., Allegan, Mich.*
www.materialtransfer.com

These liquid-level sensors work when condensation is present


Flowline

Typically, the presence of condensation substantially degrades the measurement signal strength of ultrasonic sensors, but new EchoTouch reflective ultrasonic liquid-level sensors (photo) work in areas with condensation. By orienting the transducer vertically, condensation runs off the unimpeded trans-

Cynash

Beckhoff Automation

Vertiflo Pump

ducer face to deliver reliable level measurement, says the manufacturer. EchoTouch reflective-ultrasonic level transmitters are offered in small and bulk-tank versions with optional pushbutton display or software configuration, as well as HART communication options. — *Flowline, Inc., Los Alamitos, Calif.*
www.flowline.com

Cybersecurity for legacy control systems

SerialTap (photo) is a new cybersecurity solution for legacy industrial control networks that rely on serial communication protocols, such as RS-485 and RS-232. SerialTap consists of a patented sensing device that passively intercepts serial communications on legacy industrial control networks and complementary analytics software that identifies anomalous network traffic associated with cyberattacks. The SerialTap sensor is electrically isolated from the control network, preventing any possibility of interference. All intercepted serial data packets are sent to the analytics platform via an out-of-band Ethernet connection. — *Cynash Inc., McLean, Va.*
www.cynash.com

New release of this structural analysis software

GT Strudl 2018 R1 software offers fully integrated and database-driven software for general finite element analysis (FEA) and comprehensive structural engineering design. The solution includes 10 functional areas that operate seamlessly with one another. This release includes new capabilities that allow the user to place, edit, split and copy physical members and display graphics and labels, apply loads, and set parameters for these members while maintaining mapping between other models from CADWorx Structure, Intergraph Smart 3D and more. In this latest release, the user can now automatically create standardized load combinations according to ASCE Standard ASCE/SEI 7-10 Section 1.4.1 and Steel Construction Manual AISC 14th Ed. Part 1. — *Hexagon PPM, Huntsville*, Ala.
www.hexagonppm.com

Signal transmission and functional safety combined

EtherCAT terminals (photo), part of this company's ELX Series, have been expanded through the addition of analog input terminals with built-in TwinSAFE SC (single channel) technology. These highly compact I/O terminals can be used to support applications in hazardous areas that require both intrinsically safe signal transmission and functional safety capabilities. TwinSAFE SC technology enables the use of standard signals for safety-related tasks in any network or fieldbus system. The data from a TwinSAFE SC terminal are fed to the TwinSAFE Logic, where they undergo safety-related multi-channel processing. The data originating from different sources are analyzed, checked for plausibility and submitted to a "voting" process. The space-saving ELX Series terminals, which are certified to be in compliance with the specifications of the ATEX and IECEx standards, enable direct connection of intrinsically safe field devices through Zone 0/20 based on an integrated safety barrier. The new terminal designs now make it possible to achieve new safety levels, enabling users to harness all process data existing in a system for safety technology, such as to monitor the speed of fans in areas sensitive to explosion hazards, for example. — *Beckhoff Automation LLC, Savage, Minn.*
www.beckhoffautomation.com

This pump handles solids with diameters up to 4 in.

This company's vertical wet-pit cantilever pump (photo) features a fully recessed impeller that is designed for solids pumping in light to medium slurries in many applications, including floating retention-pond pumping systems. Flows up to 1,600 gal/min and heads up to 170 ft are achievable for solids up to 4 in. in diameter. Pumps are available in lengths up to 6 ft with shaft diameters up to 5 in. Materials of construction include cast iron, 316 stainless steel, CD4, Alloy 20 and 28% chrome iron for various application requirements. — *Vertiflo Pump Co., Cincinnati, Ohio*
www.vertiflopump.com

Continuous vibration measurements improve uptime

The new 3561 FC vibration sensor (photo) improves uptime by adding remote, continuous vibration monitoring to virtually any rotating equipment. With a frequency range of 10 to 1,000 Hz, the 3561 FC detects and notifies users of conditional changes caused by critical faults, such as imbalance, misalignment, looseness and bearing wear, providing warning of impending equipment failure. The 3561 FC sensor is small enough to fit in hard-to-reach locations on equipment, and installation and setup are simple. The triaxial sensors deliver continuous measurements while the asset is in use, permitting maintenance technicians to remain at a safe distance, away from dangerous rotating equipment. — *Fluke Corp., Everett, Wash.*
www.fluke.com

New motor options for drum pumps

This company's Finish Thompson drum pumps and barrel-emptying pumps are now available with the TEFC (totally enclosed fan-cooled) IP55 motor (photo). The new motors include a powerful 1,000-W continuous-duty universal motor providing variable-speed operation from 0 to 12,000 rpm. The variable-speed TEFC versions feature solid-state control with a chemical-resistant touchpad for precise fluid dispensing and motor protection against overload and high temperatures. These motors provide 10 selectable speeds that can be easily adjusted by pushing the appropriate key on the keypad. These motors also incorporate a zero-voltage safety-release feature, which prevents the motor from turning back on after a power failure. — *Michael Smith Engineers Ltd., Woking, U.K.*
www.michael-smith-engineers.co.uk

Comprehensive monitoring for heat-trace circuits

The TraceNet Genesis control and monitoring system (photo) manages heat-trace circuit performance on process lines, tanks and instrumentation. The TraceNet Genesis system gives instant access to comprehensive heat-trace circuit information, including circuit performance history, fault analysis and circuit drawings. Using this information, maintenance personnel can predict failures or quickly restore operations, minimizing downtime. The TraceNet Genesis System provides instant on-panel access to heat-trace circuit performance trending and histories of up to six months for up to 72 heat-trace circuits. Until now, this capability was only available by networking back to a remote computer. A six-month history that reflects, for example, fluctuations or a steady decay in temperature could indicate that the system requires inspection to see whether the thermal insulation is being compromised or if an individual heater is not operating properly. By analyzing these data, engineers can assess the timing, process conditions and any undesirable symptoms as an early indicator of a future problem. — *Thermon, San Marcos, Tex.*
www.thermon.com

These dryers feature a versatile base to accommodate auxiliaries

This company's rugged fluid-bed dryers feature unitary steel bases as standard, which allow cover-lift hoists, process-air ductwork, control panels, monitoring instrumentation and other auxiliary equipment to be attached to the system as a single unit. Providing a dedicated, non-moving foundation, the bases ease process integration, add flexibility for installation and ensure that ancillary support systems may be installed on the same footprint, rather than set separately or left unspecified. Developed for use with vibrating fluidized-bed drying and cooling systems that process foods, chemicals, pharmaceuticals, minerals, plastics and other products, the support bases are carefully weighted to minimize vibratory reaction forces and to permit installation on mezzanines, light steel structures and on other above-grade locations. The bases may be fitted with secondary isolation elements to further reduce vibratory reaction forces and may be mounted on casters for mobility without affecting stability. — *Witte Co., Washington, N.J.*
www.witte.com ■

Mary Page Bailey

Fluke

Michael Smith Engineers

Thermon

Witte

Filtration Process Design and Optimization

Department Editor: Scott Jenkins

Designing a new solid-liquid filtration process or optimizing an existing one requires consideration of a number of factors aside from the type of filter that will be used. This one-page reference reviews two groups of considerations: one related to equipment, and another more related to the materials being separated.

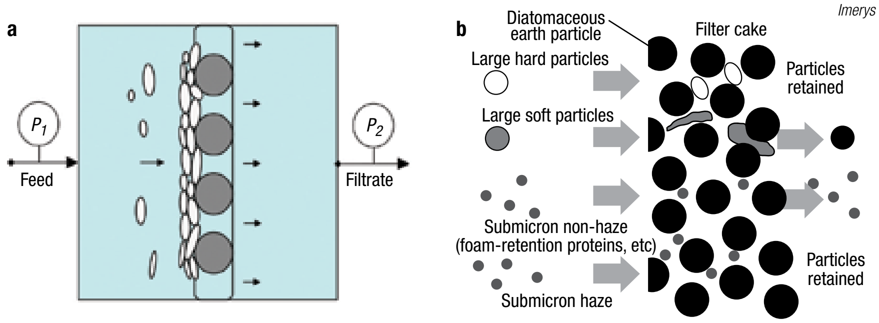

FIGURE 1. In cake filtration (a), the separation takes place on a buildup of particles (cake) on the filter medium. In some cases (b), more than simple size exclusion may be involved

Material-related issues

Solids properties. The physical characteristics of the solids being filtered have a substantial effect on the level of difficulty of the filtration process, and in turn on the appropriate type of filter and operating conditions. For example, particles that are incompressible (rigid) are usually easier to filter than those that are soft and compressible. Solids that are crystalline can be relatively easy to filter, whereas amorphous, slimy or gelatinous solids are more difficult to separate and require more complex techniques.

Particle-size distribution. The solids in a slurry are often characterized by the average particle size, which can be a useful measure. However, the particle-size distribution is also very important. The filter must be designed to retain the smallest particles that need to be removed. The tendency for particles to agglomerate, shifting the distribution toward larger sizes, may also be a factor.

Liquid viscosity. If all else is equal, pressure drop in a filtration system is higher with a more viscous liquid, meaning the flowrate is lower at a given applied differential pressure (a higher liquid viscosity results in a lower filtration rate). To reduce viscosity, liquid filtration processes are often operated at elevated temperatures.

Temperature constraints. The process temperature must not exceed the maximum allowable operating temperature of the equipment being used. Personnel safety must be considered also, with appropriate operating procedures and personal protective equipment (PPE) to minimize the risk of injury. Some products are heat-sensitive, and product degradation will limit the maximum acceptable temperature. Finally, rather than filtering hot, temperatures below ambient must be used in some cases. For example, the solids may be soluble, and reduced temperature may be needed to avoid dissolving them.

Equipment-related issues

Sizing and productivity. The main design specification of a filter is the filtration area. The required area is calculated by dividing the filtration rate per unit area, a number obtained from laboratory or pilot plant experiments, into the desired productivity, as shown in Equations (1–3).

$$\text{Throughput} = V / A \quad \textbf{(1)}$$
$$\text{Flowrate} = (V/D_t) / A \quad \textbf{(2)}$$
$$\text{Cake thickness} = Ws / rsA \quad \textbf{(3)}$$

Where:
V = total volume filtered, gal
A = total filtration area, ft^2
D_t = total time to filter, min
Ws = total weight of solids filtered, lb
rs = density (ρ) of wet cake, lb/ft^3

For example, if the filtrate rate obtained in the pilot plant is 25 gallons per square foot per hour, and the process specification is 12,500 gal/h, the required filtration area is 12,500/25 or 500 ft^2.

Filter media. Filter elements consist of a porous or coarsely open support for the filter media. The filter media is the separation point for the flow of clean filtrate into the process. Common filter media include the following: paper (disposable filter sheets made of either cellulose or non-woven synthetics); pads (disposable pads of cellulose fibers or a blend); textiles (cloths made of natural or synthetic fibers, such as polyolefins, polyesters, nylons and others); metallic wire mesh; and porous or sintered metals.

Filter aids. Precoating is a technique whereby an inert solid is coated onto the filter media to avoid plugging or blinding of the media with suspended solids or to facilitate the filter cake release. Filter aids are also used as a body feed to help keep the filter cake open for optimal cycle times (see Figure 1). The most common filter aid materials are the following: diatomaceous earth (made from silica fossils of unicellular organisms); perlite (expanded ground volcanic-lava rock); cellulose; carbon-based aids (used when the chemistry of the process liquid may react with the silica in diatomaceous earth or perlite); blends of diatomaceous earth and cellulose; calcium carbonate.

Laboratory testing

Testing in filtration processes is critical for determining the properties of solids being filtered and the ease or difficulty of the filtration. In addition, laboratory testing is important in specifying filter media, filter aids, filter area, cake space needed and cake discharge techniques. Tests are designed to analyze cake depths, operating pressures, filter media, washing and drying efficiencies and cake discharge. ■

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Benzene Production from Pyrolysis Gas

By Intratec Solutions

Benzene is the simplest and most important industrial aromatic hydrocarbon. It is a versatile petrochemical building block, and is an intermediate for several industrially important commodity chemicals and polymers, such as ethylbenzene, cumene, cyclohexane and others. Benzene is used in the production of pharmaceuticals, specialty chemicals, plastics, resins, dyes and pesticides.

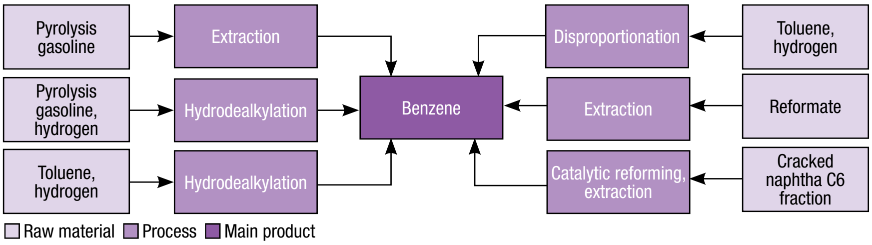

FIGURE 2. Benzene can be produced via several different pathways

The process

The following paragraphs describe a process for benzene production from pyrolysis gasoline (pygas; a naphtha-range petroleum product with high aromatics content). Figure 1 presents a simplified flow diagram.

Prefractionator. Pyrolysis gasoline is fed to a prefractionator, in which the C6 fraction is separated from the charge stock and then directed to the hydrogenation treatment section. Two byproduct streams, one composed of C5 and lighter hydrocarbons and the other of C7 and heavier hydrocarbons, are removed from the prefractionator.

Hydrogen treatment. Along with hydrogen, the C6 cut from the prefractionator is fed to a pretreatment reactor, in which di-olefinic material is hydrotreated in the presence of catalysts (cobalt molybdate on alumina). The di-olefins are converted to olefins, which are then saturated. Thiophene and other sulfur compounds in the pygas are converted to H_2S.

The reactor effluent is cooled, producing low-pressure steam, so as to condense hydrocarbons with boiling points higher than methane. The stream is fed to a high-pressure separator for the recovery of hydrogen. A gaseous stream rich in hydrogen is routed to the hydrogen purification stage, while a liquid stream is directed to the extractive distillation column.

Hydrogen purification. The gaseous stream from the flash drum is mixed with a reformer-grade hydrogen make-up, and then fed to a multistage absorber column for the removal of residual hydrocarbons. The washed hydrogen-rich gas is compressed and recycled. The extract stream, collected from the bottoms of the absorber, is fed to a distillation column, where all the light hydrocarbons absorbed from the hydrogen-rich stream are recovered as the top product. The bottoms product (the regenerated aromatic stream), is recycled to the absorber column.

Extractive distillation. In this step, the liquid C6 hydrocarbons stream from the hydrogenation treatment is fed to the middle section of an extractive distillation column. The solvent for the extraction, N-formylmorpholine (NFM), is supplied to the top of the column.

The top product is raffinate, rich in C6 non-aromatic species. The bottom product from the extractive distillation is fed to the solvent recovery column, for the recovery of benzene. NFM solvent is recovered through the column bottoms and is directed to the extractive distillation column. High purity benzene is obtained from the column overhead.

Production pathways

Until the 1930s, commercial benzene was primarily produced from coal. Since then, as new catalytic processes were developed, petroleum became the main source for this chemical. Figure 2 presents different pathways for benzene production.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce benzene was about $1,060 per ton of benzene in the third quarter of 2014. The analysis was based on a plant constructed in the U.S. with capacity to produce 250,000 metric tons per year of benzene.

This column is based on "Benzene Production from Pygas," a report published by Intratec. It can be found at: www.intratec.us/analysis/benzene-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

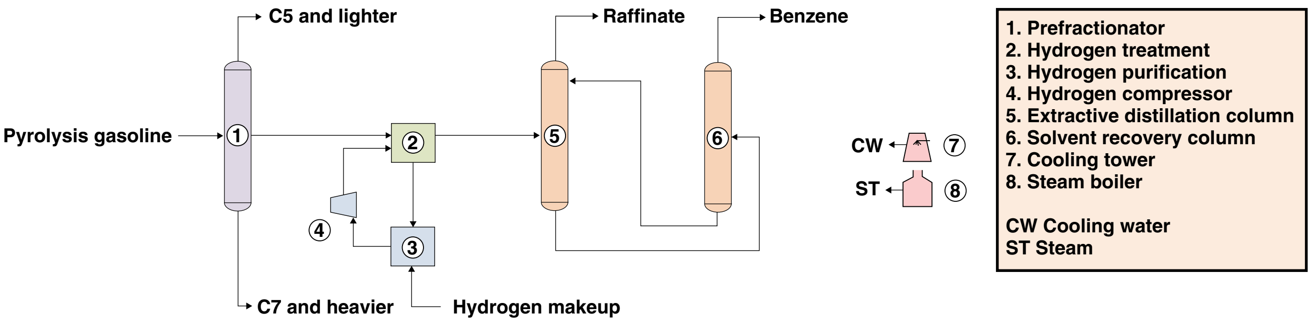

FIGURE 1. The diagram shows a benzene production process from pyrolysis gasoline

Liquid-Liquid Extraction: Generating Equilibrium Data

Equilibrium data and related information gathered from a liquid-liquid extraction laboratory "shake test" can provide information for process feasibility and column-type selection in the scaleup of liquid-liquid extraction processes

Don Glatz, Brendan Cross and Tom Lightfoot
Koch Modular Process Systems

IN BRIEF

Most chemical engineers have had the experience of dealing with problematic separations, and most have a general understanding of distillation processes. When it comes to liquid-liquid extraction (LLE) processes (Figure 1), however, the details of how these processes work are often less clear. Most academic chemical engineering degree programs do not heavily emphasize liquid-liquid extraction, and most chemical engineering graduates did not receive more than a few days of instruction on generating equilibrium data for LLE in their degree programs.

FIGURE 1. Commercial-scale liquid-liquid extraction processes often transfer solutes from an aqueous phase to a solvent

This article is focused on going "behind the scenes" and revealing more about the earliest stages of generating LLE equilibrium data. It describes how to perform a series of laboratory "shake tests" to calculate LLE equilibrium data. Furthermore, the article explains how to use those data to determine the type of column that should be used in a given LLE application.

LLE process basics

LLE is a technique that exploits differences in the relative solubility of compounds of interest (the solute) in two immiscible liquids, most often an aqueous phase and an organic solvent. In an LLE process, a liquid stream that contains a compound of interest is fed into an extractor, where it will come into contact with a solvent. To allow for phase separation, the solvent and liquid stream are immiscible, or only slightly miscible, and have different densities. The two components are mixed to promote close contact between the two components, and to allow the transfer of the solute into the solvent phase.

The two main types of columns discussed here are rotating columns and reciprocating columns. There are other methods of separation, such as utilizing static (structured packing) columns, but those find limited use due to low efficiency and lack of flexibility.

Figure 2 shows a typical LLE operation. The feed containing the solute (B) is introduced into the extractor, where it transfers into the solvent. Solvent recovery plays a large role in the overall process economics. The raffinate is stripped to remove solvent in a separate operation, typically a stripping column. The solvent in the extract stream is typically re-

covered in a distillation column.

In cases where a separation can be accomplished economically with distillation, an LLE process would not generally be used, but in cases where distillation is not feasible, LLE is often the best type of process to use. Distillation may not be feasible because of high process complexity, heat-sensitive materials, low volatility or prohibitive energy requirements. LLE can be used to break azeotropes, and when a complex distillation sequence would be required.

LLE is used across many sectors of the chemical process industries (CPI), including in the chemical industry for extracting high-boiling organic materials from aqueous streams, washing acids, bases and polar compounds from organic chemicals, in the biotechnology industry to recover compounds from fermentation broths, in the petrochemicals industry to separate olefins from parafins, in the food industry to decaffeinate coffee and tea, and many other applications.

Shake test

Before setting up a LLE process, equilibrium data should be generated to define how the solute of interest behaves in the two immiscible phases. The data generated can then be used to construct a curve for the partitioning behavior of the solute (an equilibrium curve).

Data for liquid-liquid equilibrium are generated using the shake test, a method that allows for the calculation of solvent-to-feed ratio, versus the number of stages the pro-

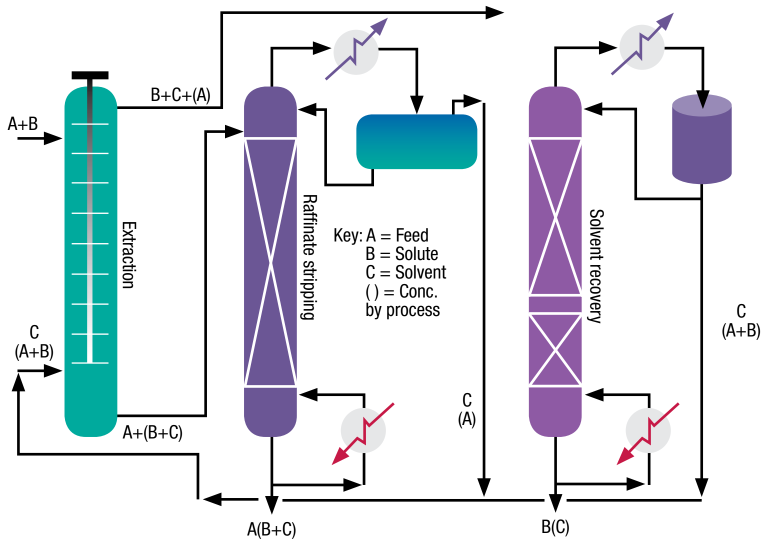

FIGURE 2. A typical LLE process includes an extraction column, a raffinate stripping unit and a solvent-recovery system

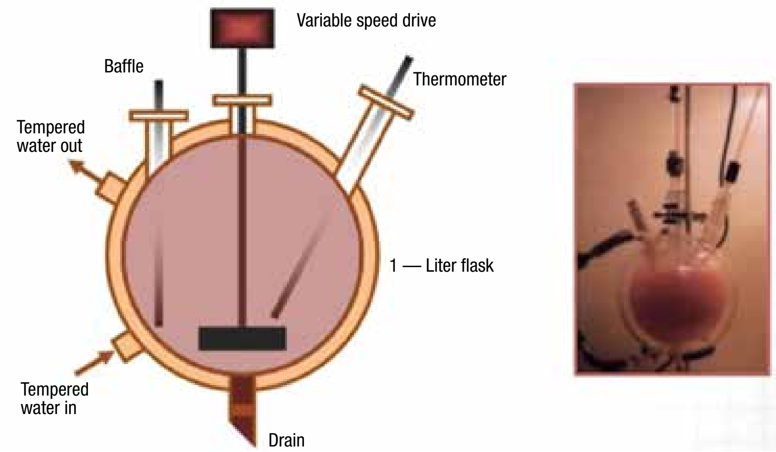

FIGURE 3. Laboratory shake tests generate liquid-liquid equilibrium data that can provide information for scaleup decisions

cess will require. Liquid-liquid extraction "shake tests" were historically done in a separatory funnel, which was hand-shaken. This is where the term "shake test" comes from. The older method of hand-shaking was complicated by variations of human practice, including varying agitation speed, time of tests and so on. It is important to note that current shake tests are much more standardized, with the same agitation speed, time and characteristics used.

The selection of which solvent to use with a particular feed depends on a number of different factors, and often requires a great deal of expertise to achieve success. Among the considerations is the relative volatility of the solvent, if it needs to be recovered (this is typical in commercial-scale systems). The ultimate decision of which solvent to use comes after evaluating the feed and testing multiple solvents. The correct solvent choice is usually the result of an experienced team.

FIGURE 4. These LLE internals will be installed into a commercial column

Shake test steps and equipment

The following paragraphs describe how to perform a laboratory shake test for collecting LLE equilibrium data. In the shake test method, a jacketed, round-bottom flask with a standard half-moon impellor and a bottom outlet is used. Tempered water flows through the jacket to control the temperature during the test. The feed and solvent are carefully weighed and added to the round-bottom flask at the desired solvent-to-feed ratio. Next, the agitator is turned on slowly and the contents are heated to the desired temperature. Typically, a mercury thermometer is used for temperature measurement, however other methods, such as using a thermocouple, can also be used.

Once the desired temperature is reached, the agitator speed is increased. For most extraction applications, the agitator is run at high speed (greater than 1,000 rpm) for exactly two minutes, at which time the agitation is shut off and the phases are allowed to separate. The authors have learned that there are two types of systems that may require more than two minutes of mixing in order to reach equilibrium. The first is when one or both of the liquids are viscous and thus, mass transfer is slow. The second type of system would be one that tends to emulsify very easily, usually due to low interfacial tension and low density difference between the phases.

For systems that emulsify, low agitation speed will be required to prevent emulsification and thus a longer mixing time is required. Upon phase separation, the time for the phases to separate should be timed to determine the separation time to reach a relatively sharp interface. The phases are then drained and weighed to determine the material balance. Samples from each phase are taken for analyses of all specified components.

After the first mix-decant sequence, the raffinate phase is returned to the flask and fresh solvent is added at the same solvent-to-feed ratio (S/F) and the procedure is repeated. This is repeated as many times as necessary to produce raffinate with the desired solute concentration (usually 4–6 times).

During the phase separations, qualitative observations are made, including what happens when the liquid phases separate. This is where a long history of experience in LLE scaleup is critical. Experience with many types of feed and solvent systems in the laboratory allows engineers to observe the performance in the laboratory shake test and use the results, together with observations, to select an extraction column technology

for pilot-plant testing and scaleup. Some of the key observations that should be made are the following:

- Does the entire system emulsify, thus resulting in very slow separation or no phase separation at all?
- How quickly do the phases separate, and after they do, is a clear, sharp interface obtained?
- Is entrainment observed in either of the phases where the entrained amount does not separate with the bulk of the liquid from that phase?
- Is there an emulsion band present that forms at the interface, and if so, how long does the band take to break?
- Are there solids that build up at the interface between the two phases (this is known as a rag layer)?

Reporting results

The shake typically returns log sheets for each of the experiments performed. If the shake tests are performed by a team of experts in LLE, you should expect a full report of the experimental results, including the raw log sheets from each of the mix-decant experiments, as well as a summary of the log sheets and analytical data. This should be presented in a table that shows full mass balances. In addition, the report should include recommendations, based on the shake test data, on the type of column that would be best suited to the separation project under discussion.

Advantages of shake test

There are several key benefits of the shake test methodology for the collection of information for LLE process scaleup. First, it is relatively inexpensive and can be completed relatively quickly. Two or three days is typically sufficient, depending on the analytical setup that is required. Shake tests allow a great deal of information to be learned quickly and without great expense. Although some solutions can move directly into pilot testing because the LLE equilibrium data are already available, having the qualitative shake test observations before pilot testing can be very advantageous to the ultimate success of the scaleup and the ultimate process (Figures 4 and 5).

At the pilot-plant-testing stage, the production-scale LLE column is designed based on the data generated at pilot-plant scale. Having robust and reliable shake-test data means the pilot testing will be more accurate right from the beginning. Results from the shake test help the engineer to select the best type of column for the process and provide a good starting point for pilot-plant testing, saving time and cost for process development.

The alternative would be to go directly into a full pilot-plant test, but doing so can introduce issues that complicate the project, such as lengthened timelines, and can drive up costs if the ideal type of column is not chosen.

The standardized shake test pro-

FIGURE 5. Modular LLE units can be installed at user sites

cedure provides a clear method for generating liquid-liquid equilibrium data. Ultimately, the liquid-liquid equilibrium data and the qualitative observations lead to a better overall solution — the best choice of LLE column for each application.

Column selection

Based on equilibrium data collected in the shake test, as well as the observed interaction between the two phases during mixing and separation, plus previous experience with LLE processes, a column type can be selected. The two main types of agitated extraction columns are rotating and reciprocating. A rotating column operates using impellers on a central shaft, plus baffling or plates (or both) to define the mixing pattern of the liquids and minimize axial mixing. The amount of shear will depend on the impeller type and the agitation speed. A reciprocating column, on the other hand, forms disperse phase droplets utilizing internals that reciprocate (up and down) at specified amplitude and frequency. Because of the uniform shear across the entire cross section of the column, this type of mixing is well suited for systems that emulsify easily.

Here are some general rules of thumb to follow when deciding which column type to use. A rotating column would be the first choice if the shake tests indicate a short separation time (on the order of seconds), and if the mixture of solvent and feed does not form an emulsion. Typically, these are systems with high density differences between the phases or high interfacial tension. Rotating columns can minimize capital costs. In cases where a slow-separating LLE system exists, rotating columns would not be ideal because of the high shear forces imparted by the tips of the impellers.

Reciprocating columns are used in cases where the shake tests indicate slow phase separation and if the system tends to emul-

A LIQUID-LIQUID EXTRACTION EXAMPLE CASE: LLE OF PHENOL FROM PHENOLIC RESIN

The following represents an example of an actual procedure used by the authors' employer to generate LLE equilibrium data for a process that was to be scaled up. The process in question required the removal of phenol from an aqueous stream produced in phenolic resin manufacturing. The aqueous feed contained about 7.5% phenol and the desired effluent concentration was less than 50 parts per million (ppm) phenol. Methyl isobutyl ketone (MIBK) was selected as the solvent. The first step in the process development was to generate liquid-liquid equilibrium data using the shake test procedure discussed in this article. A total of six mix-decant runs were performed at 30°C in a 2-L flask at a solvent-to-feed ratio (S/F) of 0.2, on a weight basis. The actual procedure utilized for this phase of testing is summarized as follows:

1. To the flask, charge 1,000 g aqueous feed and 200 g MIBK – Note the solvent to feed ratio (S/F) is 0.2. Maintain this ratio throughout all of the tests.
2. Set water bath at 31°C. Agitate at very low speed and circulate hot water through jacket until the system is at 30°C.
3. When desired temperature is reached, then agitate at high speed for 2 minutes.
4. Turn off agitation and allow phases to separate. Note the time for separation. Also make note of any emulsion formation, entrainment or rag layer (buildup of solids) that forms at the interface.
5. Drain the bottom, aqueous phase precisely to the interface. Measure the total weight of the lower phase and take a sample (Raffinate #1). Drain the upper, organic phase completely, measure total weight and take a sample (Extract #1). Analyze raffinate sample for phenol, methanol and MIBK. Analyze extract sample for phenol, methanol and water. Record results.
6. Weigh the remaining raffinate phase (feed phase after separation), and recharge to the flask. Add fresh solvent at a weight required to maintain the desired solvent to feed ratio (0.2).
7. Repeat Steps 2 through 6 for a total of six shake tests. The final raffinate sample should be less than 50 ppm phenol. If the raffinate concentration is greater than 50 ppm, then repeat shake tests until desired result is achieved.

In this particular example, the phenol concentration was progressively reduced for each mix-decant run and required all six runs to arrive at a raffinate concentration below 50 ppm. The separation time for all runs was relatively fast (23–45 seconds). A slight emulsion band occurred at the interface for the first run and all subsequent runs produced a sharp, clear interface. Based upon the results from these tests, the authors' company determined the optimal type of column to use for this application.

Subsequently, a pilot plant test was performed in a 3-in. diameter, glass-shell of the type determined from the data. The column performed perfectly for the process and the required data were generated for accurate scaleup to a production-size column. A complete extraction system was designed and built for the extraction step, followed by a distillation column for the extract phase and stream stripper for the raffinate phase. The entire system was installed and operated successfully. ❑

sify, which typically happens with low density or low interfacial tension (or both). Reciprocating columns offer higher throughput than rotating columns due to higher open flow area and uniform shear mixing, which produces droplets in a narrow size distribution. The reciprocating column has also been proven to be the better choice when a significant amount of suspended solids is present in the system.

The case in the box on p. 42 describes a specific example of how a shake test was conducted and how the data generated from it were used to make an informed decision about the scaleup to a commercial-scale LLE process. ■

Edited by Scott Jenkins

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Part 1

Avoid Common Mistakes When Specifying Burner Management Systems

While some aspects of burner management systems may seem intuitive, overcoming misconceptions in their specification and design will help to elevate overall safety

Charles Fialkowski
Siemens Industry

IN BRIEF

- AGREEING ON THE NAME
- INDUSTRY STANDARDS
- REDUNDANCY IS NOT ALWAYS REQUIRED
- NOT ALL LOGIC SOLVERS ARE EQUAL
- INTEGRATION WHILE INDEPENDENT
- MANAGE YOUR CHANGES
- MORE HARDWARE, LESS AVAILABILITY

Boilers, burners, furnaces and fired heaters, along with any other fuel-burning equipment, are considered high-risk areas within the chemical process industries (CPI). This is due to their extreme operating conditions, complex sequencing and the processing of hazardous materials, all of which result in a wide range of safeguarding measures that must be applied to prevent accidents (Figure 1). One of the more commonly used and widely accepted safeguarding approaches is the use of safety-related systems that are implemented through programmable logic control (PLC) technology.

FIGURE 1. The complexity of CPI heating processes, including boilers, burners, furnaces and more, necessitates much effort being applied to ensure their safe operation

This article presents an overview of safe burner management and reviews seven common mistakes that users of these technologies may struggle with when evaluating and specifying a modern burner management system (BMS). Performance-based standards published in recent years control the design of these technical safety systems. These standards include technology-oriented requirements covering so-called adequate implementation, and the "fit-to-purpose" tailoring of equipment. However, to obtain functional safety, this approach demands more management, competency and planning than the prescriptive requirements of original codes and standards.

Agreeing on the name

Over the years, the term "burner management system" (or BMS) seems to have spawned several aliases, such as burner safety system, combustion safeguard, flame safeguard, boiler safety system and so on. These multiple names continue to cause a great deal of confusion throughout the industry.

By definition, a BMS includes the logic system, field devices and final control elements, and is dedicated to ensuring combustion safety and operator assistance in the starting and stopping of all fuel-preparation and burning equipment (Figure 2). The Boiler and Combustion Systems Hazards Code (NFPA 85) by the National Fire Protection Agency (NFPA; Quincy, Mass.; www.nfpa.org) is an important industry standard that outlines these requirements [*1*].

In the practical sense, a BMS is a safety instrumented system (SIS) since it is an instrumented system that includes sensors, a logic solver and final control elements that is used to reduce process risk (for instance, a furnace explosion). In conjunction with the BMS, there exists the need to provide all of the non-safety-related process-control functions, also known as the combustion control system (CCS). Conventionally, the CCS provides the regulatory control func-

tions (air flow, fuel flow, drum level and so on), while the BMS ensures and maintains safe conditions as the equipment is sequenced through the various operating modes (pre-lightoff, normal operation and shutdown).

The once distinct line between CCS and BMS is getting more and more blurred. Physical and logical boundaries between the two systems are constantly being adjusted as new technologies emerge with new functionalities, diagnostics, architectures and communication interfaces. While the overall function of the BMS has not changed much over the years, a lot has changed, however, with the technology being applied. Previously, the prominent technology for a BMS was a simple, hardwired, relay logic system whose primary interface was with discrete (on/off-type) field devices, and the operator interface was a handful of lights and pushbuttons. The communication interface was nothing more than a few relay contacts wired over to the CCS.

With the adoption of PLCs, smart analog field devices, internet communications and Windows-based human-machine interfaces (HMIs) on modern-day BMS designs, one can begin to appreciate that the once-distinct difference between the CCS and BMS is no longer very clear. This is all the more reason for industry to agree on a single, consistent name.

The bottom line is, if the equipment you are dealing with has a flame, users should agree that the instrumented system dedicated to provide safety functionality to reduce risk will be called the burner management system. Once the name is clear, the next step would be to develop a complementary scope document to help identify the major BMS components, such as its central processing unit (CPU), inputs and outputs (I/Os) and engineering and operator workstations, along with a safety requirement specification that will define two key elements of the BMS — what it is supposed to do and how well it must perform to complete its function.

Industry standards

Major accidents involving fired equipment are rare today, mostly because of the extensive industry experience and good engineering practices that have been developed over the past several years.

Nevertheless, professionals still seem to be sometimes confused over which standard they should reference when implementing a burner management system. Table 1 provides a summary of some of the most relevant non-industry-specific standards available today.

FIGURE 2. A modern, safety-rated PLC-based BMS may include several components, including sensors and final control elements

If the BMS is to be designed in accordance with a particular code or standard, then this should be clearly listed in a plant's safety requirement specification. Any reference to a code or standard must be specific (for instance, "the system is to be designed in accordance with NFPA 85") while avoiding broad catch-all references, as they may be inappropriate and could potentially increase system scope, add confusion and offer no corresponding benefit.

In addition, many types of fired equipment may be subject to application-specific good engineering practices, such as those outlined by NFPA 87, Recommended Practice for Fluid Heaters.

In some cases, this may appear to cause problems with designers wishing to take advantage of newer approaches and technology that currently is not prescribed as an approved method. These novel approaches may in fact, still be appropriate, since all of the recently updated NFPA standards have incorporated an equivalency provision, where alternative designs could be considered compliant as long as certain conditions are met. This process is generally known as the safety lifecycle. The key steps are as follows:

- Identify the hazardous events that could result in unacceptable consequences
- Identify the safety functions in your BMS that could prevent these hazardous events
- Determine the risk reduction (for example, performance requirement) for these safety functions
- Allocate safety functions to your BMS to be designed and managed to achieve this performance
- Document the functional and integrity requirements in a design specification
- Verify that design and management practices are sufficient to meet the performance requirements
- Document and implement operational and maintenance procedures to support performance requirements
- Manage changes to process equipment and the BMS to ensure continued safe operation

The technical report ISA-TR84.00.05 was issued by the International Society of Automation (ISA; Research Triangle Park, N.C.; www.isa.org) to help users address various aspects of these steps specifically for BMS applications. Simply put, prescriptive industry standards from organizations like NFPA, the American Petroleum Institute (API; Washington, D.C.; www.api.org) and others may find some complementary effects by leveraging the performance standards from ISA and other groups, such as the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch) and American National Standards Institute (ANSI; Washington, D.C.; www.ansi.org), to ensure that the methods for managing the risk associated with

TABLE 1. SELECTED INDUSTRY STANDARDS	
NFPA 85, 86 & 87	Prescriptive codes, standards and recommended practices that provide specific details of what must be implemented for burner management systems based on the application (boiler, oven, furnace, heater and so on)
IEC 61511 or ANSI/ISA 84	Performance-based, international standard for functional safety of safety instrumented systems for use in the CPI
TR.84.00.05	ISA's technical report written specifically for the application of ANSI/ISA 84 (IEC 61511) to burner management systems
FM 7605	Approval agency standard that requires PLC-based burner management systems to be in compliance with IEC 61508 (functional safety certification for PLCs)

FIGURE 3. Certified safety PLCs offer numerous benefits over standard PLCs, such as built-in safety concepts and extensive diagnostics

the hazards suit both the owner's operational requirements, as well as gain the approval from the authority having jurisdiction.

Redundancy is not always required

The statement "no single point of failure" has been one of the most often misinterpreted BMS requirements in the industry over the past 30 years.

For most people using PLC technology, a common misconception is that compliance can only be achieved by configuring the PLC's CPU in a dual-redundant architecture — most think intuitively that "if one is good, then two should be better." Unfortunately, in terms of safety system performance, things are not as intuitively obvious as they may seem. In some cases, it has been shown that simplex (non-redundant) systems can in fact be safer than dual systems.

The primary concern here was that the industry was moving away from a technology that was considered relatively failsafe. This meant that it offered a high degree of certainty that the dominant failure mode was toward the safe condition or where all of the circuits would become de-energized (turned off) in the event of a system failure.

As modern microprocessor-based PLC systems started to replace previous-generation relay logic systems, it was realized that these systems, while offering numerous engineering and operational benefits, did not, however, offer the same level of safety in the event of a failure.

Industry prescriptive standards, such as those developed by NFPA, tried to overcome this by developing an exhaustive list of requirements that would protect against a system failing toward a potentially dangerous condition or state.

One of these requirements was that the PLC-based BMS should be designed specifically so that a single failure in the system does not prevent an appropriate shutdown. Many simply interpreted this to mean that to be able to protect against a CPU failure, the BMS must utilize redundant CPUs in their design to avoid such a condition.

For some systems, this might mean that in order to protect against a single system failure and still maintain the ability to shut down the process, the PLC will need redundancy. This need for redundancy will be necessary to improve the overall failure mode of the system, and despite marketing promises, will not improve the overall availability of the system. For some systems, this capability has already been designed and built into the system and is not necessary. Therefore, it is important to realize that all systems are not the same, and that one needs to have a clear understanding of the failure modes of the system, as well as the supported redundancy architectures (single, dual or triple). While redundancy is not necessary to achieve this requirement, it might be, depending on the system selected.

Not all logic solvers are equal

When considering PLC designs for use in BMS applications, the industry generally recognizes two options: safety-configured and safety-rated. In some regards, either of the two could be implemented to meet the intention of the industry standards. However, there are serious differences and considerations that require understanding.

First, one needs to understand that a general-purpose PLC and a safety-configured PLC are, for the most part, the same thing. A safety-configured PLC is an industrial-grade, general-purpose PLC that is specifically configured by the original equipment manufacturer (OEM), systems engineer or end-user for use in safety applications. In some cases, the PLC manufacturer might have even received a certification from a third-party agency that its particular configuration is capable of meeting a certain performance level.

Both ISA and IEC standards limit the amount of performance these systems can claim, based on the level of assessment, and they also cap the highest claimed level of performance to be an order of magnitude less than a safety-rated PLC.

The concern with using safety-configured PLCs is that many are never fully tested or accurately assessed for the level of protection measures that are to be implemented in order to detect faults and to ensure appropriate responses are initiated. Simply adding an external device to the PLC to monitor its "heartbeat" is never enough. For some PLC systems, this most likely will require additional hardware (CPU, power, I/O modules and so on) and even software programming (for instance, process flow checks or internal watchdog timers) such that in the event of a system fault, the system is configured to ensure that it still has the means to stop the process if hazardous conditions are present. Diagnostics alone do not necessarily meet this requirement — the diagnostics must have the ability to bypass the program and automatically take the system to a safe state.

Safety-rated PLCs (Figure 3), on the other hand, are purpose-built and certified by independent third-party approval agencies, such as Technischer Überwachungsverein (TÜV) or Exida, to meet high safety requirements. Most safety-certified PLCs offer fault-tolerant architectures and extremely high diagnostics-coverage

capabilities that make them ideal for use in BMS applications. While there may appear to be an initial purchase-price premium for a safety-rated PLC, most studies indicate that the overall cost difference will become marginal after applying all of the necessary hardware and software additions that are required with the standard PLC.

Integration while independent

Just like an automobile needs both acceleration and braking functions, any industrial plant that has a need for heated medium, regardless if it is used for processes, utilities or emissions control, will ultimately need equipment that will provide both control (CCS) and safety functions (BMS). Traditionally, these control strategies would have required physical separation between the main logic units of the CCS and BMS (Figure 4). However, today, the industry has started to see an evolution in how these control systems can be implemented, particularly for simple, low-risk applications (for example, single-burner, single-fuel systems) where two separate control systems just seems like too much. In addition, industry standards have started to loosen their long-standing position on requiring two separate systems to provide complete independence between the control (CCS) and safety (BMS) systems. Users are now starting to consider a combined strategy, where these two systems are now integrated into one where they can realize the benefits of lower system costs and less complexity (one is easier to manage than two), as long as they continue to manage their risks.

As recently as 2015, NFPA 85 included a statement that permitted this single-system concept that could be implemented as both a BMS and CCS as long as certain conditions were met. One of these conditions was that the PLC system must be certified via a third-party agency to be SIL 3 capable, which is a measure of safety performance as defined by the IEC 61508 standard. Again, this condition was only for certain applications (single-burner) and for specific qualified equipment (SIL 3 rated). Functional safety standards like IEC 61511 do permit combined control and combustion safeguarding in one system. Other standards, like the 2015 edition of NFPA 85, now explicitly allow combining combustion control and combustion safety in the same logic solver for certain applications.

However, several design issues must be considered and properly addressed in order to maintain or improve safety performance. A properly designed combination combustion-control and combustion-safeguarding system can enhance the safety lifecycle by reducing engineering, operations and maintenance errors and improving combustion safety.

Manage your changes

During the early adoption years of PLCs being used for BMS applications, one NFPA requirement stated that "logic shall be protected from unauthorized changes." This required some PLC manufacturers to implement burned-in, electrically erasable programmable read-only memory (EEPROM) technology to protect their programming. This practice became so commonplace in the in-

FIGURE 4. A programmable BMS may include cause-and-effect diagrams and enable users to deeply examine process-safety functions, whereas a traditional CCS will mainly focus on regulating functions, but new systems are beginning to integrate these capabilities for some simple applications

dustry that many of the code-enforcement inspectors started to expect this technology to be in place, regardless of whether it was even needed.

Burning memory into an EEPROM was not the only way to prevent unauthorized program changes, and was considered a very old-fashioned way to offer non-volatile memory. Users wanted programmable systems specifically for their software flexibility, and burning memory into EEPROMs worked against that goal. In fact, burning in EEPROM prevented any online changes altogether. Today, many safety-rated PLCs incorporate both software and hardware security features that will serve to prevent unauthorized changes, while still allowing (with caution) online changes.

For any type of programmable system, management-of-change rules are often quite different for the CCS and BMS. CCS control functions are not as critical, and many sites allow not only control parameter changes, but control strategy changes without much formal administrative intervention and approval.

Safety requires far more administrative control with justification and approval required before any changes are made. One easy way to help enforce this is to never have control and safety together within one programmable controller. Some in the safety community even have a rule that dictates different manufacturers and perhaps different technologies be used so that entirely different configuration languages and procedures act as additional means of enforcing the management-of-change procedures.

When we look at the requirements stated by NFPA regarding protection against unauthorized changes, the intent is clear (protect against unauthorized changes) but the implementation (how, when and why) is not. In this case, one can turn to the guidance of performance standards, such as IEC 61511 or ANSI/ISA 84, for direction. These standards further explain that management-of-change procedures shall be in place to initiate, document, review, implement and approve changes to the SIS (BMS). Furthermore, they add that procedures also need to be in place where changes outside the BMS could affect the system performance (for instance, re-design of the CCS). The goal is simple — maintain your BMS safety integrity over the system's entire lifecycle.

More hardware, less availability

Industry standards, such as NFPA, have long recognized that to properly design a failsafe PLC-based BMS, several failure modes inherent to microprocessor-based technology must be addressed, including the following:

- Unsafe failure conditions of the I/O circuits (fail-on, fail-off)
- CPU faults, such as processor stalls, loss of communication with I/O modules, failure to execute program logic and so on

In 1996, a leading PLC manufacturer at the time published an influential article [2] that described several methods that should be used to protect against specific PLC failures, one of which was the use of an external watchdog timer. A watchdog timer is a technique that bolts onto the PLC and monitors for logic and I/O execution, and in the event of a fault will automatically cause the system to fail safe. While this technique may be necessary to improve the safety performance of a general-purpose PLC, studies have shown that the use of these timers may, in safety-rated PLCs, provide no benefit, and will increase the nuisance trip rate, since this capability is already built in, tested and certified. To make matters worse, one of the leading industry certification bodies updated its own standard in 1999 to require that all PLC-based burner management systems conform to the SIL-rated IEC 61508 standard, as well as have external watchdog timers. Some liken this to the herd mentality, where decisions are made following the lead buffalo. In this case, the manufacturer might have noticed a deficiency in its design and developed a solution, while others just followed along. While this superfluous requirement may still be found in specifications today, in 2014, a paper was published [3] where many of these "extraneous" hardware requirements are addressed and debunked.

In light of these updates to industry standards and accepted practices, as well as the growing adoption of new technologies, it is increasingly important that users of burners and other fired equipment understand the significance of a BMS and its uniquely critical role in process safety. ■

Edited by Mary Page Bailey

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Part 2

Reduce Risk and Cost with a Lifecycle Approach to Process Safety

Better upfront planning and management can lead to safer, more productive processes throughout every phase of operation

Pete Skipp
Rockwell Automation

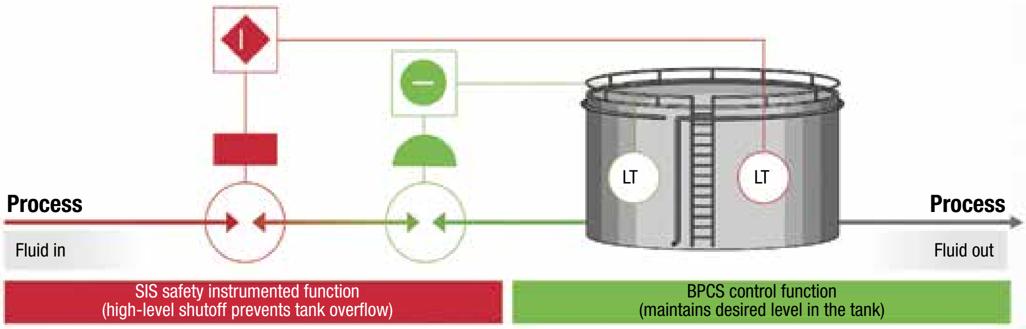

FIGURE 1. A safety instrumented function (SIF) has a specified safety integrity level (SIL) that is necessary to achieve functional safety. The SIL applies to the SIF, which is the combination of the sensor, logic solver and final element — not the programmable logic controller (PLC)

IN BRIEF

A standards-based approach to process safety — one that actively addresses risks across a plant's lifespan — can lead to safer chemical processes, fewer safety functions and lower operating costs. The problem, however, is that too few companies employ this approach, and expose themselves to greater risk of a catastrophic incident as a result.

The U.S. Chemical Safety Board (CSB; Washington, D.C.; www.csb.gov) pointed to this problem in a video that examined process safety in the 10 years following the major petroleum-refinery explosion in Texas City. The video cited multiple instances where risks went unaddressed in chemical processing operations, sometimes resulting in fatal incidents. A CSB official also said every incident his organization investigated in the 10 years after the Texas City incident was preventable. "There has not been one investigation we've done where we found the incidents were unavoidable," the official said.

Today, as many companies in the chemical process industries (CPI) look to replace decades-old safety-related technologies, they have an opportunity to put an end to this trend by rethinking their approach to process safety.

Why is process safety falling short?

One problem many CPI companies face is that they simply do not have dedicated resources for process safety. As a result, they are unable to spend sufficient time to help ensure requirements for specifying, designing and implementing a safety instrumented system (SIS), as well as helping to ensure that it is properly maintained throughout its life with functional safety assessments and periodic audits.

A SIS is a system consisting of sensors, logic solvers, such as a programmable logic controller (PLC), and final elements, such as valves, motors and pumps. A SIS is specifically designed to implement one or more safety instrumented functions (SIF). Figure 1 illustrates the role of a SIF within a chemical process.

In some cases, companies will specify a certified PLC with a specific safety integrity level (SIL), because it meets their expected highest level of protection. However, they may not apply the same rigor to the field devices, such as sensors and final ele-

Process safety lifecycle overview

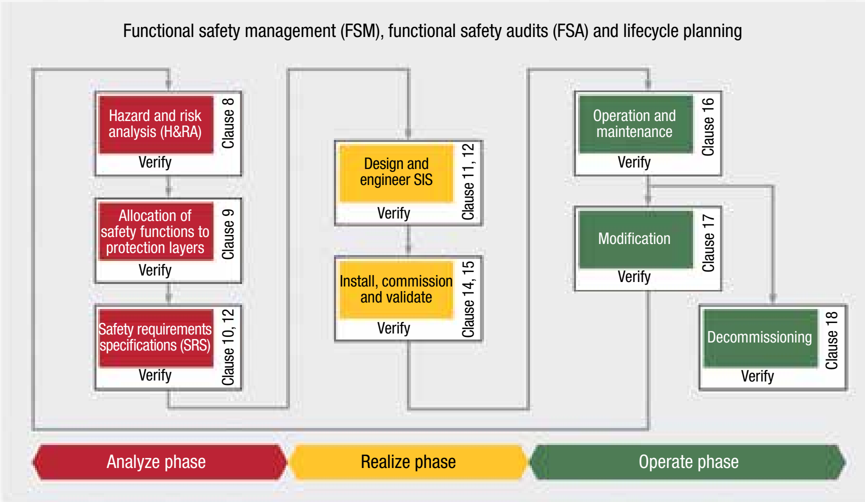

FIGURE 2. International industry standard IEC 61511 can be used to formulate an overarching approach to process safety

ments, nor to other layers of protection that are needed for effective process safety.

Another issue is that companies will often strive for compliance when they deploy a SIS, but not ensure the same level of compliance for its functional-safety management aspects throughout its lifespan. For example, they may not proof test the system's SIFs to make sure that they maintain the target SIL.

Independent reports, such as the U.K. government's Health and Safety Executive (HSE) report on control system failures, help illustrate where failures are causing or contributing to industrial accidents. The report found that 44% of failures were caused by an inadequate specification, due to either a poor hazard analysis or an insufficient assessment of the impact of control-system failure modes on the specification. Meanwhile, 15% of failures were caused by inadequate operation and maintenance and 20% were caused by changes after commissioning.

Introduced in 2003 by the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch), the international standard IEC 61511 is based on a lifecycle approach to process safety. This standard is written to address these known issues with implementation and is largely written by end users, for end users.

The definitive standard

A methodical and standards-based approach can help companies better understand their process safety risks, then implement the right level of protection. This approach can also help companies design maintenance and support requirements into SIFs to reduce the risk of safety-integrity performance degrading over time.

The functional safety standard IEC 61511 should be the basis for a standards-based lifecycle approach to process safety. It defines the requirements that must be met, not only in designing and implementing a SIS, but also in maintaining it for the entire operating life of the system.

There is more upfront work involved in applying this standard, due to its analysis phase and management aspects. Managing the safety loops throughout a system's lifecycle also creates more work, but the benefits from this added effort are significant: the likelihood of fewer safety risks, a properly sized SIS and increased process uptime.

Moving through the lifecycle

A lifecycle-based safety approach (Figure 2) has three main phases of execution: analysis, realization and operation, each of which is covered by the specific clauses included within IEC 61511. When moving through these phases, it is important to remember that every task must be verified by someone independent of those who performed the task. These three main phases are further detailed in the following sections.

Analysis. The purpose of the analysis phase is to understand how much risk exists within the process, and then define where and how that risk can be mitigated. Processes such as the HAZOP (hazard and operability) study identify the risks and generate the safety requirements specification (SRS) and techniques, such as inherently safer designs, alternate layers of protection, alarm management and SIS implementation, to mitigate the risk.

The SRS is a document, or collection of documents, that aim to fully describe the functional and performance requirements for each SIF identified during the hazard and risk assessment. Examples of the details required in this document are:

- The function of each SIF
- The safe state of each SIF
- The expected demand rate, or how often it is expected to operate; and the spurious trip rate, or how often it is expected to fail safely
- The failure modes and behavior of the SIF when faults or failures are detected
- The extremes of environmental conditions in which the SIF operates

Realization. During this phase, a functional design specification can now be developed from the SRS. This document defines how the safety functions defined in the SRS are implemented using selected SIS technology, thus meeting the SRS.

In the design and engineering portion of this phase, technology is selected to help implement the required behaviors. There is no requirement that the technology be certified by groups like TÜV Rheinland (Cologne, Germany; www.tuv.com) and exida (Sellersville, Pa.; www.exida.com), but choosing such solutions can help users meet the required integrity with less documentation. The SIS can then

UPGRADING A SIS SUCCESSFULLY

Recently, a chemical manufacturer created and implemented a new, internal safety standard for its global facilities. The standard was designed to help the company work toward its goal of zero accidents in all areas of its operations.

The company knew it needed to update its decades-old SIS to bring the facilities into compliance with the newly implemented internal safety standards. Several types of risk analyses were conducted to identify compliance levels with the new corporate safety standard. These included conducting safety integrity level (SIL) and hazard and operability (HAZOP) studies at its production facilities. The studies helped the company identify the SIS upgrades needed to bring its facilities into compliance with the new standard. More than that, however, they brought attention to the obsolescence risks faced by some of the equipment used in the facilities.

As a result, the company migrated to a new SIS that brought its facilities into compliance while also reducing downtime risks associated with aging equipment. By staying ahead of current safety requirements, the solution helped the company prepare for future expansion. The systems also helped the company stay ahead of potential SIL requirement increases without the need for another SIS upgrade in the future. ❑

be installed and validated in a documented manner to confirm that it meets the requirements outlined in the SRS.

Operation. Organizations must ensure that the identified and implemented risk-reduction measures are maintained throughout a plant's or process' lifespan. This even includes identifying how hazards will be managed during decommissioning.

Safety integrity performance will degrade over time, which is why regular proof tests are critical. Also, any changes to a SIS can impact safety. Clause 17 of IEC 61511 provides guidance for SIS modifications. Modifications to a SIS can occur for several reasons, including the following:

- Failure of a component (such as an I/O module) where the same part number is no longer made by the original manufacturer. This modification could entail fitting a new model or moving signals to another I/O module
- A SIF is not performing up to its expectations. For example, it is failing frequently, and the operating company needs to redesign equipment to get the SIF back to peak performance
- The process plant itself is undergoing modifications, which in turn impact the SIS equipment. This could be as simple as a setpoint change or as complicated as fitting new instrumentation or valves

Verification at each step of the safety lifecycle is essential, as there are many areas throughout the lifecycle when exposure to safety risk is heightened if procedures are not properly followed and verified. For example, during the analysis phase, and specifically during the hazard and risk assessment, if application of safeguards is not quantified — or assumed — or is not specific enough to achieve the claimed risk reduction, it could lead to a situation where a SIF has a risk-reduction target that is less than is actually required. Therefore, the company is operating at a greater risk.

This can happen when a procedure-based safeguard that requires multiple human interactions is poorly written and the people responsible for implementing the safeguard are poorly trained. Another common example of increased risk during the analysis phase is when a "pre-alarm" in the control system is identified as a protection layer and has an inadequately defined operator response or is regularly ignored, or even removed or disabled, because it was originally acknowledged as a nuisance alarm.

One example of an increased risk during the realization phase is when the design team does not correctly follow or verify the requirements defined in the SRS, leading to the SIF not operating as defined by the hazard and risk assessment. This can also occur in situations where the function has been correctly implemented but the producer is mandating a change during the factory acceptance test because, in the producer's opinion, it is not operating the way it should be operating, resulting in the SIF providing insufficient risk reduction.

Lastly, during the operations phase, similar examples as those listed above can increase safety risks, if not verified. For example, an alarm function identified as a safeguard is removed by maintenance, even if some level of management of change is followed, but the impact analysis for the change did not check whether the alarm removed was specifically identified as a safeguard in the first place.

Decision time

The many CPI companies seeking to replace their decades-old SIS today face a choice: they can continue with the status quo or grandfathering of legacy systems, which assume that what has been providing protection for the last 20 or more years will continue to do so. Conversely, they can take a more proactive, standards-based approach that addresses their plant's process safety needs across its entire lifecycle. The latter can reduce the potential for catastrophic safety incidents, help to ensure that operations teams are living up to corporate leadership's expectations for safety and create overall safer and more productive chemical operations. The benefits of this approach are certainly worthwhile, especially in exchange for a little extra planning and management work. ■

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Experimental Methodologies to Verify Distillation Simulations

Presented here are practical considerations concerning the equipment and methods used for experimental verifications of simulations

Glenn Graham, Patrik Pednekar and Don Bunning
MATRIC

The use of process simulation tools for modeling distillation columns is invaluable for designing plant-scale columns. However, it can be difficult to know if the simulator is generating accurate predictions. Additionally, there are potential problems associated with distillation columns that process simulators do not address. Hence, experimental distillation studies are quite important to either verify the simulation results or to provide a path forward to improve the simulations (Figure 1). As a followup to a previous article that discussed the needs for experimental validation [*1*], this article presents the experimental methodologies used for validating process simulations.

FIGURE 1. Experimental studies are important to either verify distillation simulations or to provide a path forward to improve the simulations

Batch, continuous or pilot?

Once the need for experimental validation of distillation simulations has been identified, a decision must be made as to whether the experiments should be conducted in a batch column, a stand-alone continuous column or a continuous column within a pilot plant representing all, or part, of the entire process. Below are some of the initial considerations for each of these options:

- *Laboratory batch column*
  - Relatively simple and inexpensive to set up
  - Will not represent the same composition profiles, temperature profiles or reboiler residence times as a continuous column
  - Can validate some or all of the required vapor-liquid equilibrium (VLE) predictions from a simulator
  - Can demonstrate, qualitatively, decomposition, byproduct generation, foaming and fouling issues
  - Can help to decide if distillation is a viable option for the separation scheme
- *Stand-alone continuous column*
  - More difficult and expensive to set up than a batch column, but less costly than a full separation train
  - The same composition profiles, temperature profiles and reboiler residence times that will be experienced in the full-scale column can be experimentally modeled
  - VLE predictions can be validated for full-scale composition profiles and liquid/vapor (L/V) ratios
  - Can demonstrate, more quantitatively, decomposition, byproduct generation, foaming and fouling issues
- *Continuous column in pilot plant with recycles*
  - All the same considerations as for the stand-alone column
  - Byproducts may form in other parts of the process that build up and affect the column
  - Products and byproducts from the column may affect other process equipment

Often, initial experiments are conducted in a batch column, and if warranted, followed by a continuous column. The size of the experimental column is another important issue. Sizing is discussed in the next sections.

Batch column considerations

If the VLE for a binary system is unknown, the ultimate path forward is to experimentally measure the VLE using an ebulliometer. However, the expense and effort of this method may not be warranted in many cases. If there is a reasonable degree of confidence in the physical property model for the distillation simulator and there is a desire to just check the model or tweak its parameters, experimental testing in a simple laboratory batch column may be acceptable. A batch column is relatively easy to set up and to operate. A significant amount of useful data can be collected from experiments with this equipment.

However, the use of a batch distillation simulation program that accounts for tray volumes and process changes with respect to time, may be necessary to use the labora-

tory batch-column data for physical property validation. Many engineers conducting process simulator work are simulating continuous processes and do not all have experience with batch distillation simulators. To properly evaluate experimental batch data, simulations must be run in a corresponding batch mode so that the experimental data can be compared to the corresponding simulator prediction. The effort required to develop and run the batch simulation needs to be taken into consideration.

For systems operating between about 5–10 mm Hg and atmospheric pressure, the traditional equipment used for batch validation purposes is a 25–50-mm dia. vacuum-jacketed column with Oldershaw-style trays (Figure 2). The kettle can be charged with an initial composition of the chemicals of interest, and brought to total reflux. After reaching steady state, the reflux ratio can be set at a finite value to remove a small distillate sample of the light-boiling compounds, and a sample of the kettle can be taken at the same time. Keep in mind that as distillate is removed, the reflux ratio is temporarily being lowered and the separation changed, so take as small of a sample as possible. Collecting samples at total reflux significantly reduces the concern about heat effects, since the L/V ratio will be essentially 1.0 throughout the column, no matter how much condensation occurs in the column.

It is important to know the actual tray efficiency for the experimental column with the chemical system of interest whose physical property model is being validated. If necessary, the tray efficiency of the laboratory column can be measured using a known binary system that is as similar as possible to the actual chemical system. This experiment should be conducted at nearly the same flowrates and pressure that will be used for the batch-distillation experiment with the actual chemical system. Compare the predicted and actual tray efficiencies for the known binary system and adjust the efficiency prediction for the actual chemical system.

FIGURE 2. Shown here is a laboratory Oldershaw distillation column with a vacuum jacket

Make sure that the compositions at the top and bottom of the column are in a range that will allow accurate analyses. At very low concentrations of the heavy-boiling component at the top of the column or light-boiling component at the bottom, the analytical errors may represent several theoretical stages in the column.

The heat loss throughout the column should not be so great as to cause major changes in the tray activity (froth) between the top and

FIGURE 3. These photos show unjacketed Oldershaw-style column sections with (right) and without (left) liquid and vapor traffic. These column sections were custom-made with a reduced number of holes for high L/V ratios and with side ports for a thermocouple or sample apparatus. Glass allows visual observation of the tray activity (froth, foaming and fouling issues)

the bottom of the column. The worst case is to have dry trays at the top of the column and nearly flooded at the bottom. Experimental setups with tall columns, high operating temperatures, and/or small diameter columns will be especially prone to troublesome heat-loss problems.

It is likely that some of the experiments will involve charging the kettle with the actual chemicals and removing the bulk of the kettle charge overhead as distillate cuts, possibly every 5–10% of the kettle charge. Data collected from such batch tests will provide an indication as to whether distillation is a viable option, help determine the difficulty of the separations, and generate samples that can be used for physical property validation.

One experimental approach with such batch testing is to set the reflux ratio at a value that is relatively high, but not so high as to prevent the experiment from being completed in a reasonable time. However, this method raises two additional concerns. Heat loss becomes important, since it can change the L/V ratio in the column and cause the effective reflux ratio throughout the column to be different than what would be expected based on the measured reflux ratio. Also, the column will never be at steady state, since the compositions within the column are continuously changing. The negative effects from the unsteady state problem can be reduced by increasing the kettle volume, relative to the column size, and increasing the reflux ratio. These changes will slow the rate of composition change in the column. A batch-distillation simulator will likely be required to correctly evaluate the data from such experiments.

Another experimental approach involves removing a series of distillate cuts at a finite reflux ratio and putting the column on total reflux after each cut. After the column reaches steady state at total reflux, a small distillate and kettle sample are removed at a high, but finite reflux ratio, then the column proceeds with the next cut (using a finite reflux ratio). This method is more time-consuming, but it solves the heat-loss and unsteady-state problems. It may be possible to simulate these data using a continuous distillation simulator.

Equipment considerations

Size Selection. For small-scale experimental continuous-distillation columns that are intended to model the operation of a full-scale column, significant judgement is required to choose the equipment size necessary to conduct useful validation experiments while minimizing costs. Generally, larger-scale columns will provide better data but the cost of the experimental effort will increase with size. Several concepts are discussed below that should help with the trade-off between the quality of the data and the cost of the effort.

Generally, to minimize the cost of the experimental work, it is desirable to use the minimum size that will allow meaningful scaleup data to be collected. For columns using Oldershaw-style trays, the minimum recommended diameter is 50 mm with a minimum tray spacing of 50 mm. For smaller columns, especially for chemical systems with high surface tension, the tray activity (froth on tray) becomes more erratic and difficult to quantify. In addition, smaller columns are more difficult to control. Even with the use of insulation and heat tapes (instead of vacuum jacketing with silvering), the higher surface-area-to-volume ratio of columns smaller than recommended makes it more difficult to run the column adiabatically. However, in certain cases, a smaller column may be adequate.

For columns using random packing instead of trays, the column diameter is recommended to be at least 5–15 times the packing diameter, depending on the packing. In the case of Pro-Pak 0.16-in. packing, the minimum recommended column diameter is 20 mm. For structured packings, columns with diameters as small as 20 mm may be used, as is the case with Sulzer EX gauze packing (designed specifically for laboratory columns).

Other sizing considerations include the following:

- If the distillation column is part of a pilot plant that includes other process equipment, such as a reactor, there may be a minimum size for this other equipment. Material balance calculations will then dictate the distillation column size
- If a reactor, distillation column or other major equipment already exists, the desire to utilize the existing equipment may affect the choice of the size of the pilot unit and of the distillation column
- To ensure accurate data for all important flows and compositions, the considerations of managing the smallest critical stream may determine the size of the pilot unit and the distillation column
- If samples need to be generated, their volume requirements will be an important factor in the sizing decision
- The availability of feed materials or the cost of disposing of wastes may place an upper limit on the pilot plant size

Cost estimation. Cost is always a consideration in the sizing of an experimental unit. Although costing is beyond the scope of this article, Ref. 2 provides good insights into the cost issues involved with designing and constructing a pilot plant.

Materials of construction and equipment design. If the column pressure is 1 atm or less, glass should be considered as the material of construction for the column. Glass allows visual observation of internal flows, foaming, and fouling issues (Figure 3). Visual observations are not only important for collecting reliable data for model validation, but will be invaluable for plant equipment

design considerations.

If trays are to be modeled, an Oldershaw-style tray is recommended for the contactor. The standard Oldershaw design works well for many chemical systems. However, for processes with extreme L/V ratios, high surface tensions, high viscosities, or residence-time concerns, several manufacturers have the capability to create custom trays. If the column will use packing, then open tubes can be utilized for the column sections, with a screen at the bottom to support the packing. At the feed point and between packed sections, there should be a collector-distributor section that collects all the liquid from the bottom of the packed section above and redistributes it properly to the next packed section below. Usually, a tube-style distributor is adequate (for 50–75-mm dia. or less, with one tube that introduces liquid to the center of the packing). There will be a recommended maximum packing height for each packed section that can be provided by the packing vendor. Reflux to the top of the column can be accomplished with either a liquid-dividing head, or a system of flowmeters and pumps that measure and control the reflux and distillate. The liquid-dividing head uses a timer mechanism to alternately divert the entire condensate flow as either column reflux or distillate product. The liquid-dividing head has the advantage of simplicity, but does not allow for direct measurement of the flows, and the splitter device can become stuck if the electromagnet is misplaced or there are fouling issues. For packed columns, the reflux must be distributed properly to the top packed section.

If custom trayed column sections are to be purchased, it is strongly recommended that a port be incorporated into the column at every two to three trays, which could be used for a thermocouple or a liquid sample extraction point (it may be possible to install both in the same port). This arrangement will allow the temperature and liquid composition profiles to be determined directly and will be invaluable for any system with uncertainty regarding the physical properties or the generation of byproducts. For packed columns, these ports could still be useful, especially for thermocouples. It may be difficult to obtain a liquid sample from the packing, but it may be possible to collect vapor samples with the proper sampling arrangement.

The choice of the reboiler residence time should be given ample consideration, since this time can affect the amount of degradation and byproduct formation that occurs in the base of the column. Also, the reboiler configuration and heat source should be designed to avoid excessive skin or localized temperatures.

Insulation. Knowing the liquid and vapor flowrates is critical for a distillation column that is producing simulator validation data. Since heat loss will affect these flows, how the column is insulated is an important issue to consider. If the column is glass, the two main options are vacuum-jacketing or insulation with heat tape. Vacuum jackets traditionally have the interior surface silvered to reflect radiant heat, and there is usually a non-silvered vertical "line" (about 6 mm wide) the full length of the column section on the front and back that allows viewing into the column. For relatively short distillation columns that are not very hot, vacuum-jacketing is acceptable. However, although this is a simple and elegant means of insulating the column, there will be some heat loss and additional internal reflux. The other alternative, insulation with heat tape, allows a column to run at near adiabatic conditions no matter the operating temperature (Figure 4). It can be used on glass and metal columns, and has the advantage of reducing the cost of the column sections, since the expense of the vacuum jacket is avoided. This method is somewhat more cumbersome, in that it requires wrapping each column section with insulation and heat tape. This inconvenience is offset by the increased confidence that it provides better experimental data. The traditional way to implement this method of insulation is to wrap the column with two layers of insulation, with heating tape wrapped between the layers. One thermocouple is placed next to the column with another one near the heating tape (on the column side). The input for the controller is the temperature difference, with a setpoint of zero degrees. This represents no heat loss or gain. Several sections of heat tape and insulation should be installed based on the expected temperature profile for the column. This will minimize the range of column temperatures for each heat tape and insulation section, so that each section can be as close to adiabatic conditions as possible.

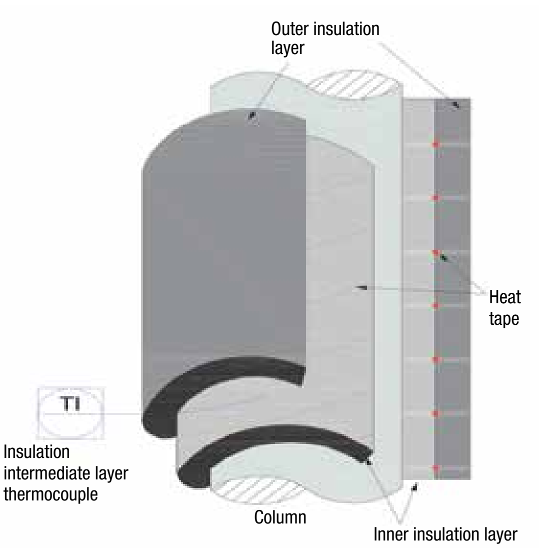

FIGURE 4. An unjacketed distillation column with insulation and heat tape is shown here. The heat tape is wrapped between two layers of insulation (source: R. Nunley, MATRIC [*3*], used with permission)

Air leaks. Air leaks into vacuum columns, especially those operating under high vacuum, can obviously affect the vapor flowrates, if severe enough. However, at leak rates well below this threshold, the leaked oxygen may contribute to byproduct formation, particularly if the air is entering the reboiler. In addition, the flowrate of the leak will be additive with any nitrogen blowback for pressure and differential-pressure sensors, and will contribute to light-boiling component losses from the condenser to the vent system. The loss of lights in this manner can introduce significant errors if not properly considered.

Concerns and recommendations

The relative liquid-to-vapor flowrates (L/V ratios) and tray or packing efficiencies must be understood to use the experimental data to validate the physical property models used in the simulator. The following discussion provides some guidance to assist with that task.

New distillation columns should be checked to ensure that all sensors

are reading correctly and that heat losses are controlled or, at least, understood. The efficiency of the trays or packing should be determined at operating conditions near the design conditions. Ideally, these tests should be conducted using a binary chemical system, with known VLE, that is as close to the actual system as possible, just as for the calibration of a batch column. This method eliminates the uncertainty due to incorrect VLE predictions, leaving the relative vapor and liquid flowrates and the contactor efficiency as the unknown parameters to be determined initially.

If there is a concern about whether the liquid and vapor flowrates are accurately known in the experimental apparatus (that is, heat losses are not minimal or not well understood), use the following procedure. Simulate the column at a pinched condition (for instance, reflux-to-distilate ratio = R/D = 0.5) and vary the Murphree Efficiency between 40 and 80% to ensure that the predicted distillate and bottoms compositions are relatively insensitive to tray efficiency. It may be necessary to change the feed composition or to adjust the R/D ratio in the simulation to ensure that the separation is not sensitive to the Murphree Efficiency. Make sure that accurate analyses are possible at the predicted distillate and bottoms compositions. Then run the experiment at those conditions in the actual column. Since the VLE curve is known, if the distillate and bottoms compositions from the experiment do not agree with the computer simulation, these differences are an indication that the internal flows are different than those used in the simulation. The differences could be due to inaccuracies in the flow sensors, or heat losses from the column causing internal reflux.

After any problems are corrected from the previous test, the column should be evaluated with respect to efficiency. The column should be operated at conditions as similar as possible to the design conditions for the actual system. Keep in mind that the efficiency of a vapor-liquid contactor is affected not only by the L/V ratios, the pressure, and the composition, but also by the absolute flowrates. The amount of bubble/froth activity on a tray will affect the interaction between the phases, and, therefore, the efficiency.

For packing, liquid flowrates will affect the film thickness, liquid residence time, and surface turbulence; vapor flowrates will affect the degree of vapor mixing, vapor residence time and surface turbulence of the liquid, all of which will affect the packing efficiency or HETP (height equivalent to a theoretical plate). Ideally, the efficiency will be estimated using a software tool, or equations from the references provided earlier [*1*], and the calculations compared with the actual efficiency. This comparison will calibrate the efficiency predictor tool. If sample points are available in the column, the actual column profile can be compared with the computer simulator predictions to show if deviations are consistent throughout the column or tend to vary at one end of the column relative to the other.

Finally, the column can be operated with the actual chemical mixture. The efficiency prediction tool can be used to estimate the contactor efficiency for the actual system, incorporating any tuning adjustment. Now, the relative and absolute internal liquid and vapor flowrates are known and a good estimate of the contactor efficiency is available. Any discrepancies between actual and predicted composition profiles (and temperature profile) can be attributed to errors in the distillation simulator's physical property model, and the parameters for this can be adjusted as necessary.

Concluding remarks

Key points to consider when contemplating the need to experimentally validate distillation simulations include the following:

- Without experimental validation, it is difficult to know if the simulations are accurate.
- Byproduct generation, foaming and fouling are difficult or impossible to predict by process simulators.
- Experiments should be conducted to validate distillation simulations and to determine if other non-simulated problems will occur.
- The main concepts that affect the separation in a distillation column are the VLE, L/V ratios, and contactor efficiency (pressure also plays a role).
- Major experimental options include the scale and whether to use a batch column, a stand-alone continuous column, or a continuous column within a pilot plant.
- A laboratory batch column may be able to provide adequate initial data for validation purposes.
- If an experimental continuous distillation column is to be utilized, several factors must be considered regarding its size.
- Heat loss should be minimized or properly accounted for in any experimental column.
- Initial experiments should be conducted to ensure that L/V ratios can be set at desired values and that contactor efficiency can be predicted.
- After ensuring that the experimental apparatus functions properly and is well understood, experiments should be conducted with the actual chemical mixture. ■

Edited by Gerald Ondrey

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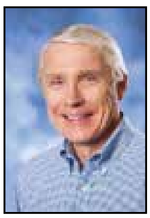

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Calculate the Wetted Surface Area of Pressure Vessels

This article provides a comparative study of two approaches to protect ASME semi-elliptical pressure tanks from overpressure in the event of a fire

Babak Firoozi
Oilcor, Inc.

Calculating the wetted surface area is a crucial step to protect American Society of Mechanical Engineers' (ASME) pressure vessels from overpressure in the event of a fire. The historical approach relies on an analytical approximation, using a linear equation to calculate partial surface area of 2:1 semi-elliptical (SE) heads that has been published [*1*]. This article presents a rigorous numeric analytical method and compares partial surface area calculations of 2:1 SE heads using both methods.

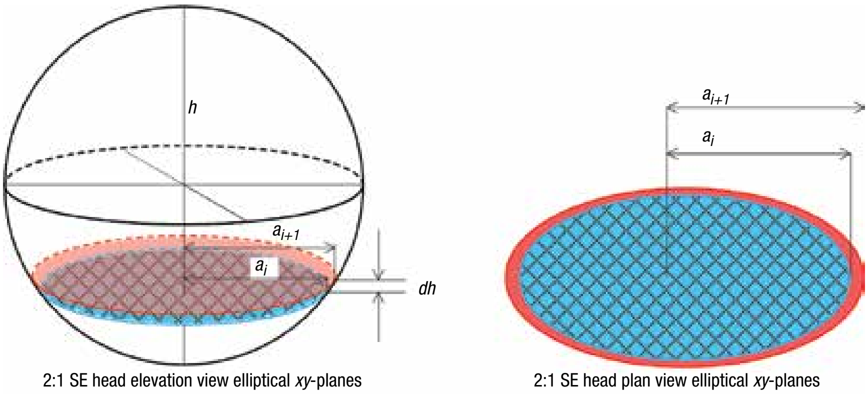

FIGURE 1. This figure shows the cross-section view of the SE heads of horizontal pressure vessels, in both elevation view (left) and plan view (right)

FIGURE 2. In the event of a fire, the fluids inside a partially filled ASME pressure vessel with 2:1 SE heads will absorb heat through the wetted surface, which is shown here in a darker shade of blue

Pressure relief from fire

The loss of fluids from enclosed ASME pressure vessels as a result of overpressure due to fire is a major safety concern at chemical process industries (CPI) facilities. Such an event can not only lead to worker injury and damage to mechanical assets, but has the potential for catastrophic losses to the facility, the surrounding community and the environment, as well. Fire is often the cause of the greatest relief load through a pressure safety valve (PSV), and thus becomes a critical aspect of appropriately sizing the PSV.

Fluids in a vessel absorb the heat of a fire through the wetted surface area (Figure 2). The fluid's increase in volume due to vaporization then reaches a pressure that exceeds the pressure capacity of the fixed vessel volume. The expanded fluid must be relieved through the PSV to avoid rupturing the pressure vessel.

Per American Petroleum Inst. (API) Standard 521, the head absorption from fire is calculated by $Q = C_1 A_{WS}^{0.82}$, in which C_1 is a constant and A_{ws} is the wetted surface area [2]. The absorbed energy across the wetted surface area provides heat required to boil the liquid.

NOMENCLATURE	
SE	Semi-elliptical
S	Surface area
R	Radius
D	Diameter
V	Volume
h	Liquid level, 0 to *D*
dh	Differential of liquid level for each *i*
i	Number of *xy*-planes, from 0 to *n*
h_i	Liquid level at *i*, $h_i = dh*i$
a_1	Semimajor axis at h_i
All dimensions are in consistent units	

Surface area calculations

Heads of ASME pressure vessels are typically in the shape of an oblate spheroid at a ratio of 2:1 (Figures 1 and 2). An analytic approximation for wetted surface area of both 2:1 SE heads has been presented as S=2.168Dh.

The shape of ellipsoids is well defined by the general equation

$$x^2/a^2+y^2/b^2+z^2/c^2 = 1$$

and its total surface area is defined by Knud Thomsen's formula [*1*]:

$$S = 4\pi\left[\frac{(ab)^p + (ac)^p + (bc)^p}{3}\right]^{1/p}$$

Where $p = ln(3)/ln(2)$.

An ellipsoid's partial surface area is not defined but can be calculated by numeric analysis as the sum of finite segments of frustums along any axis. Table 1 shows the equations used for this calculation. A frustum between each elliptical *xy*-plane of any shaped ellipsoid (for example, an egg) along its *z*-axis is calculated using the following Equation *3*:

$$S_i = \frac{\pi}{2}(a_{i+1} + a_i + b_{i+1} + b_i)$$

$$\sqrt{dz^2 + \frac{1}{4}\left[(a_{i+1} - a_i) + (b_{i+1} - b_i)\right]^2}$$

A 2:1 SE head is an oblate spheroid (Figure 1), of which $c = a$ and $b = a/2$. The calculation of each frustrum from a_{i+1} to a_i then reduces to:

$$S_i = \pi\frac{3}{4}(a_{i+1} + a_i) \cdot$$

$$\sqrt{dh^2 + \left[\frac{3}{4}(a_{i+1} - a_i)\right]^2}$$

Per the Pythagorean theorem, the semi-major axis (a) of each successive *xy* plane is

$$a = \sqrt{2Rh - h^2}$$

TABLE 1. CALCULATIONS USED TO DETERMINE THE WETTED SURFACE AREA OF ASME 2:1 SE HEADS OF PARTIALLY FILLED HORIZONTAL VESSELS

Wetted surface area (analytic approximation method) of both heads:

$$S = 2.168Dh \quad (1)$$

Calculating wetted surface area (rigorous numeric analysis)

$$a_i = \sqrt{2Rh_i - h_i^2} \quad (2)$$

$$S_i = \pi\frac{3}{4}(a_{i+1} + a_i) \cdot \sqrt{dh^2 + \left[\frac{3}{4}(a_{i+1} - a_i)\right]^2} \quad (3)$$

$$S = \sum_{i=1}^{n} S_i \quad (4)$$

Volume at liquid level = *h* (analytic approximation) of both heads

$$V = \frac{\pi}{6}(3R - h_i) \cdot h_i^2 \quad (5)$$

Volume at liquid level = *h* (rigorous numeric analysis)

$$A_i = \frac{\pi}{2}a_i^2 \quad (6)$$

$$V_i = \frac{dh}{2}(A_{i+1} + A_i) \quad (7)$$

$$V = \sum_{i=1}^{n} V_i \quad (8)$$

Wetted surface area and volume of the cylindrical section of the horizontal vessel

$$S = L \cdot 2R\cos^{-1}\left(\frac{R-h}{R}\right) \quad (9)$$

$$V = L\left[R^2\cos^{-1}\left(\frac{R-h}{R}\right) - \left(R-h\right)\sqrt{2Rh - h^2}\right] \quad (10)$$

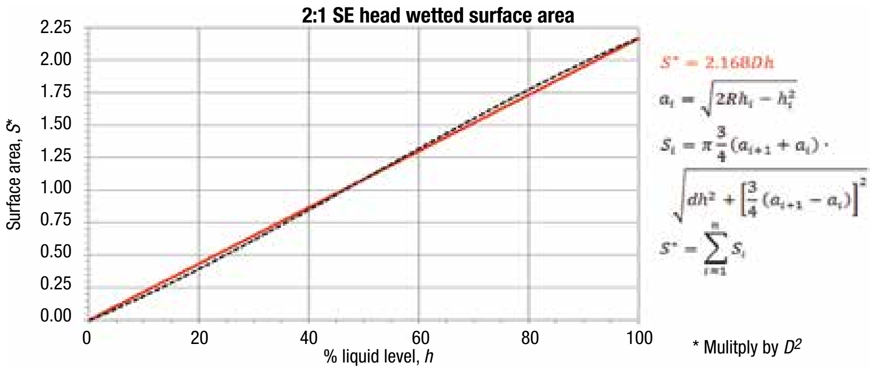

FIGURE 3. This comparison shows close correlation between the results achieved when the analytic approximation and the rigorous numeric analysis were used to determine the wetted surface area of the pressure vessel

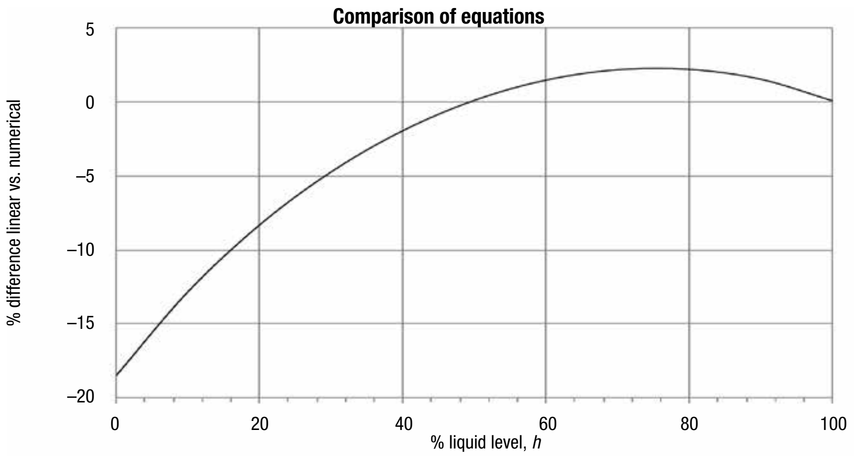

FIGURE 4. Shown here is the percentage error of the analytical approximation versus the rigorous numeric analysis that was shown in Figure 3

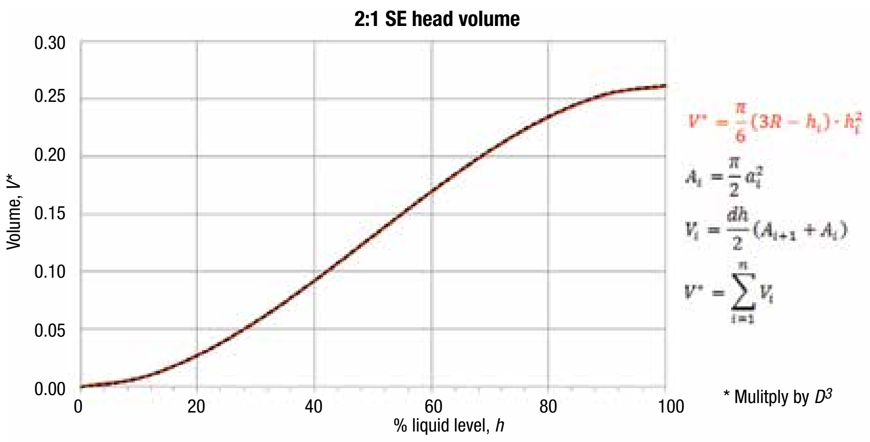

FIGURE 5. This graphical comparison shows the results from the analytical approximation versus the rigorous numeric analysis of a partially filled tank volume

(Figure 1), along the height of the *z*-axis [3].

It is helpful to use a standard spreadhseet or other software because 100 or more frustums should be calculated for the best accuracy.

Liquid volume

The liquid volume of a vessel may be required to determine the total relief load (total liquid inventory) during a fire. The liquid volume of a partially filled 2:1 SE head is calculated by

$$V = \frac{\pi}{6}(3R - h)(h^2)$$

which is derived from the volume calculation of a spherical cap [3]. By rigorous numeric analysis, the volume is calculated as a sum of all zones of each cross-sectional *x* plane. As shown in Figure 3, the volume calculated by both methods are the same.

Comparison

Compare the calculation of the wetted surface area of a 2:1 SE head by analytic approximation (S=2.168Dh) against a rigorous numeric analysis (Figures 3 and 4). The analytic measure is a linear function of liquid level h. The rigorous numeric analysis results in a non-linear function of h.

The numeric method's algorithm divides the head into a minimum of 100 *xy*-planes. The sum of finite segments of frustums between each *xy*-plane along the height of the *z*-axis (liquid level h) is the wetted surface area of 0 to h.

By Figure 3 and Figure 4, we observe that the maximum difference of wetted surface area calculated by analytic approximation versus rigorous numeric analysis is less than 3% at about 75% liquid level. Typically fire relief load is calculated at 70–80% liquid level.

Discussion

A linear equation S = 2.168Dh gives a very close approximation of the wetted surface area of a 2:1 SE head as compared to a rigorous numeric analysis. Of course, the linear equation is much easier to apply; however, for the engineer experienced with common spreadsheet software, the rigorous numeric analysis gives an exact result. ■

Edited by Suzanne Shelley

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Improve Energy Management to Reduce Your Facility's Carbon Footprint

This article describes an approach that uses data analytics for finding and addressing root causes of process deviations that reduce energy efficiency in key plant utility systems, and shares three case examples

Edwin van Dijk
TrendMiner N.V.

Discussion about climate change has been taking place for many years and is perhaps more relevant today than ever before. This debate has led to global initiatives to reduce the carbon footprint of chemical process industries (CPI) facilities, which is high on the agenda of nearly every country. Regulations have been established on a global, regional and local scale to reduce greenhouse gas emissions, and these regulations heavily impact CPI process operators. To achieve mandated emissions-reduction goals and demonstrate regulatory compliance, many CPI companies are adopting the ISO 50001 standard, which aims to improve the organization's energy performance and make reduction of climate change a key part of their corporate strategy.

BASF Corp. recently articulated this concept as core to its own operating strategy when it wrote: "For us, energy efficiency is the key to combining climate protection, conservation of resources and competitive economic advantages [*1*]."

Reducing an industrial facility's carbon footprint is not only good for the environment, it's good for the bottom line, as well, because sound energy management often contributes to more efficient operation, reduced fuel usage and improved overall profitability. Within the CPI, energy use is often one of the largest components of a company's overall expenditures.

Using concerted energy-management strategies to reduce costs is not new, but has become more important due to mandated regulations and leaner profit margins in many sectors. Most CPI companies have formalized energy-management programs and use various automation and control technologies to help minimize energy costs. It is clear, however, that many process operators need to take their efforts to the next level, by monitoring and optimizing energy use in real time, and leveraging data generated via the Industrial Internet of Things (IIoT).

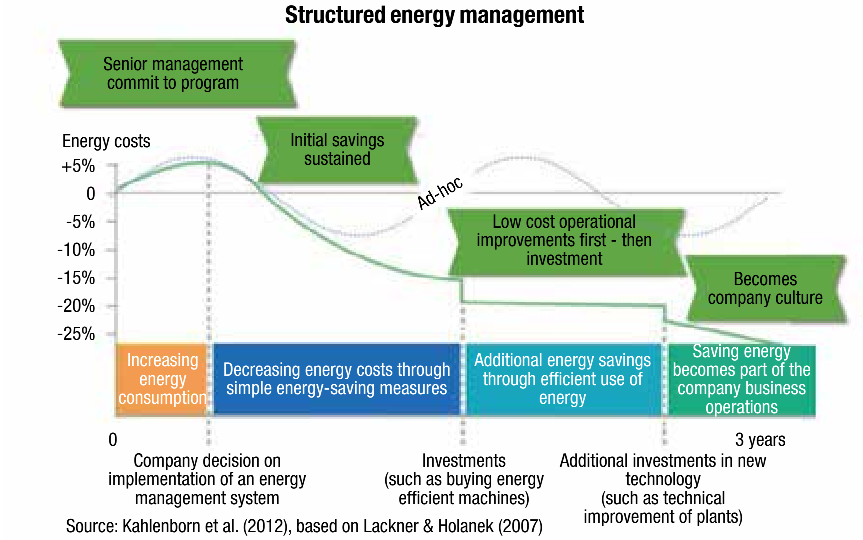

FIGURE 1. At many CPI sites, quick wins in energy savings may have already been carried out. Additional investment in new technology, such as self-service analytics, can continuously help to reduce your organization's carbon footprint

For many years, process data have been captured in data historians. Such data are valuable and need to be unlocked and leveraged for continuous improvement in efforts to lower the carbon footprint of the company. In recent years, advanced data-analytics techniques have been used by some large companies, to help optimize their larger onsite energy-related issues.

However, such time-consuming, centrally led, data-modeling projects are typically less well-suited for process-related optimization efforts that are carried out more locally and require subject matter expertise. More recently, the availablilty of tools that put advanced analytics capabilities in the hands of subject matter experts (SMEs), such as process and field engineers, has helped to bring these powerful capabilities to the plant and process level. In some cases, this allows SMEs to manage as much as 80% of energy-related improvements that will contribute to corporate goals for reducing the company's overall carbon footprint.

Improved energy management

Global interest in Industry 4.0 [*2*] and IIOT has accelerated digital transformation in process manufacturing sectors, and specifically in the commodity and specialty chemicals industries. Many companies have engaged in technology pilots to explore options for reducing costs, increas-

FIGURE 2. This figure shows energy consumption per production line for three consecutive years showing performance against the reference year. The right side of the figure shows sensor-generated, time-series data that provide a graphical representation of operational performance

ing overall equipment effectiveness (OEE) or regulatory compliance. One of the best ways to leverage these new innovations is to apply advanced industrial analytics to production data generated by sensors. Every piece of data provides insight and unique opportunities for improving energy efficiency.

Options to trim energy use

In general, energy savings can be achieved in various ways via the following efforts:

- Changes in daily behavior (such as switching off the lights)
- Installation of more energy-efficient equipment
- Improved equipment maintenance
- Ongoing process optimization
- Efforts to ensure operation of equipment systems within their best operating zones

Process optimization and the ability to optimize asset performance offers one of the biggest opportunities for energy savings, but such efforts require a deeper understanding of operational process data and asset-related data (such as data collected by the data historian) [*3, 4*].

Monitor and analyze key items

The major process and asset-related energy consumers include water, air, gas, electricity and steam (WAGES) systems, and the performance of each of these processes can be directly or indirectly analyzed using sensor data. Too often, utilities and energy are neglected at the plant level, since there are more-pressing needs and analyzing inefficiencies in WAGES systems is laborious.

Specifically, looking for inefficiencies across the various WAGES systems is time-consuming because these critical plant utilities are used all across assets, plants and sites. For example, a plant could have hundreds of unit operations that require nitrogen or steam. For an individual to find the root cause of what may have created an increase in overall steam usage would require looking at possibly hundreds of tags from the data historian — and would essentially be akin to finding a needle in a haystack. It is rare for plant personnel to have the time available to dive deeply into an investigation like this. Most of the time, no one would even look at the steam flowmeter unless a major issue had arisen.

SMEs such as process, operations and maintenance engineers have deep knowledge of production processes. Such individuals are in the best position to understand the process behavior and assess root causes when using advanced analytics tools tailored for their daily tasks (called self-service advanced analytics), wihout the need to necessarily gather data manually, create a complex data model or validate the results.

Through a self-service analytics tool, the data can be descriptively analyzed to determine what has happened. And if a long period of performance can be assessed, the performance can be better understood. Sometimes, certain issues happen only a couple of times per year but can have a big impact on overall energy consumption (for instance, a trip that causes a shutdown). Discovery-analytics capabilities allow the SME to understand what has happened, and through diagnostic analytics, the organization can then start monitoring the performance of the site more effectively.

Since asset performance is contextualized by the process in which any given component is functioning, the best operating zones or performance windows need to be extracted from actual process behavior rather than theoretical data. Based on the historical data, best operating zones or best performance envelopes (also called the "golden fingerprints") with regard to energy consumption can be created to monitor good and bad behavior. Additionally, monitoring live operational performance can be used for predictive analytics, for instance, to predict the impact on downstream performance of behavior an hour or more upstream.

Practical use cases

Using best-in-class, self-service analytics tools is easier and more efficient than creating data models from scratch. To stick with our previous

FIGURE 3. Predictive maintenance can reduce the fouling of heat exchangers in a factory

FIGURE 4. The cooling of industrial water-pumping equipment can be monitored using advanced analytics

example, for an SME to compare hundreds of tags to see what may have caused a spike in the unit's battery-limit steam meter would be very time-consuming. By comparison, using an analytics tool, SMEs can quickly get answers to relevant questions such as:

- Is the air or demineralized-water usage in my steam or nitrogen plant abnormal?
- Is there anything that correlates with this abnormal usage right now?
- How can I quickly figure out why my WAGES are abnormal so I can take timely corrective action?

With traditional data-modeling tools, these questions could take weeks to answer, which is why they are often neglected. There are many instances where advanced self-service analytics tools have been successfully used to analyze, monitor and predict process and asset performance.

Case 1. Energy consumption within a cooling water network. A large number of reactors were consuming cooling capacity from the utility network for cooling water. Sufficient cooling capacity is critical for many of the reactors, because thermal runaway reactions could occur when the available capacity is insufficient. To avoid this hazardous situation, advanced analytics capabilities were established to monitor the cooling capacity in real time.

Early warning signals were created to alert for actual problematic situations, thereby minimizing false-positive alarms that could be triggered by measurement noise or spikes in the data. Once the process operator or engineer receives a warning, there is ample time to re-balance the reactors and de-prioritize other equipment so that the critical ones have access to the maximal cooling capacity. This helps overall energy consumption and process safety to remain within target boundaries.

Case 2. Energy consumption related to a burner oven. A burner oven was suffering from multiple trips, causing production losses and increased gas consumption. Through advanced process-data analytics, multiple previously unknown root causes were found to be responsible for the trips. With this increased understanding of the process, monitors were added to alert the key stakeholders. The monitors allow the SMEs to take appropriate action when a specific cause of a trip occurs, and thus avoid a trip from happening.

The events are now also automatically annotated with the explanation of the root cause. This way, the organization is actively learning to con-

trol the process based on combining actual process behavior with subject matter expertise. With downtime reduction achieved, gas consumption has also decreased significantly, but more importantly, the energy consumption is being improved continuously over time.

Case 3. Predictive maintenance to reduce fouling of heat exchangers. In a reactor with subsequent heating and cooling phases, the controlled cooling phase is the most time consuming. Fouling of heat exchangers increases the required cooling time. However, scheduling maintenance too early leads to unwarranted downtime, while scheduling it too late leads to degraded performance, increased energy consumption and potential safety risks. To enable timely maintenance, a cooling time monitor was set up, extending the asset availability, reducing the maintenance cost and safety risks. All of these benefits, including controlled energy consumption, ultimately led to 1% or more overall revenue increase of the production line.

Continuous improvement

In general, finding and solving root causes for process deviations and anomalies results in a more energy efficient operation. Monitoring the live production performance allows for better control of various production parameters, including energy consumption. When the total energy consumption of a specific year is taken as a baseline, the monitoring of performance against corporate goals becomes possible.

For example, Covestro AG, a leading manufacturer of polymeric materials for many CPI applications, initiated three major energy-savings projects for its polyether plant in Antwerp as a part of its energy-savings goals and ISO50001 directives. Self-service industrial analytics solutions were implemented for online detection, logging and explanation of unexpected energy consumption (providing both root-cause analysis and hypothesis generation), and for comparing the results with the reference year 2013. Using specific formulas and calculated tags, various energy-consuming operations are monitored and controlled. By monitoring the performance against the reference year, the company was able to see that energy consumption has been effectively decreased year over year, to meet its corporate goals. More importantly, with a growing knowledge and insight into the process, Covestro is continuously improving its overall performance.

Closing thoughts

Energy management is not new; many companies have a structured energy-management program in place. However, new self-service analytics tools now allow SMEs to analyze, monitor and predict process and asset performance, which can help them to meet company-wide carbon footprint goals. And when the so-called low-hanging fruit for energy savings has been picked and more knowledge is applied to improve operational performance, SMEs get the added benefit of improving overall profitability and increased safety. ■

Edited by Suzanne Shelley

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Cybersecurity: Building Resilience from the Inside Out

Cybersecurity is no longer a far-fetched concept relegated to science fiction or conspiracy theories. It is a major and growing global risk across all industry sectors

Kristina Drage-Arianson and Don Crouch
Lloyd's Register

Given the increasingly central role of digital technologies, data and connectivity, cybersecurity is widely accepted as a major risk to all industries and society as a whole. Furthermore, as technology becomes more accessible, the skill pool of associated "dark arts" expands — and the risks increase (Figure 1). According to the 2018 Global Risk Report from the World Economic Forum (www.weforum.org), cybersecurity is the third-largest risk faced by businesses. The report also estimates that cyber-crime activities will incur costs of around $8 trillion over the next five years across the entire economy. Furthermore, findings from telecommunications giant Verizon, in its 2017 Breach Investigations Report, found that 95% of "phishing" attacks (disguised emails aimed at stealing information) that led to a breach were followed by some sort of software installation. These points underline the fact that industries must be proactive in dealing with cybersecurity issues.

The view from the boardroom

Too many businesses make cybersecurity a priority only when they have been attacked, and although many recognize the lack of adequate resource allocation to this critical aspect of business resilience, they also admit that they do not have enough understanding of the latest information, security implications and their own vulnerabilities.

Executives are beginning to recognize that those individuals responsible for cyberattacks are highly skilled, are not constrained by the law and are driven by a range of motivating factors. While there is significant activity across many industries to mitigate the potential impacts of cyberattacks, many experts still feel that the level of cybersecurity response may be insufficient or misdirected.

While adequate measures may be in place to protect against data theft and hacking, operations remain vulnerable, making interruptions a likely outcome in the event of a cybersecurity breach. Experts have also suggested, for example, that most oil-and-gas and chemical processing companies do not yet have in place the systems and resources required to precisely determine the source of cyberattacks, or with what frequency they occur, in order to implement preventative measures.

FIGURE 1. Cyber-crime is on the rise as digital technologies continue to proliferate across the process industries, and malicious individuals become more adept at targeting companies' vulnerabilities

The type of data being stolen is particularly revealing. While sensitive personal information like financial or health records remains a key focus, hackers are increasingly targeting higher-value data relating to infrastructure systems and large industrial facilities. Based on research from cybersecurity firm FireEye (Milpitas, Calif.; www.fireeye.com), 18% of the data exfiltrated through cyberattacks in Europe in 2016 related to companies' industrial control systems, building schematics and blueprints, while a further 19% related to trade secrets.

The threat is real

The potential for performance improvements by using live process data as an input to an operation is largely uncontested in operations and manufacturing. On the whole, it is understood that these types of data are essential to improving operational performance and that data technologies provide opportunities for more accurate risk assessment and control of safety-critical systems (Figure 2). But statistics confirm that the threat of unauthorized data access and cyber-crime is serious and growing — and hacking of these systems or data can directly impact a company's ability to control its own

safety systems.

According to the Cost of Cyber Crime Report from the Ponemon Institute (Traverse City, Mich.; www.ponemon.org), the number of breaches is up by an average of 27.4% year over year, and 86% of companies around the world reported that they had experienced at least one cyber incident in 2017.

In 2012, the attacks on Saudi Aramco and Qatar's RasGas entity raised the profile of industrial cybersecurity. At Saudi Aramco, hackers replaced data on hard drives with an image of a burning U.S. flag, prompting the then U.S. Secretary of Defense Leon Panetta to label the incident, "a significant escalation of the cyber threat." Two years later, it was reported that between 2010 and 2014, hackers had stolen source code and blueprints to U.S. oil and water pipelines, as well as power grids, and had infiltrated the U.S. Department of Energy's networks on some 150 occasions. More recently, high-profile breaches at Sony, U.K. telecommunications provider TalkTalk and others have accelerated and amplified concerns about the risks associated with cyberattacks. Understandably, businesses of all sizes are looking at how they can improve their resilience.

It is important that industries are prepared to equip themselves with mitigation measures to defend against cyberattacks. As industries become increasingly dependent upon digital technologies, operational and technology security is a key concern across all sectors.

The chemicals, oil-and-gas, nuclear and renewable-power-generation sectors are diverse regarding the implementation of cybersecurity technologies. Wind- and solar-power generation tend to be on the forefront of advanced connectivity and analytics, while oil-and-gas tends to lag in the same technology area.

While the information technology (IT), data management and communication ends of the operational spectrum have been seen as a major opportunity for cyber theft and corruption, this focus must expand as industries change. To date, this has been a focal point of cybersecurity efforts in all energy and manufacturing sectors. However, the next big area of cybersecurity concern for the oil-and-gas and chemical processing sectors is the rapid advancement of connectivity among previously isolated operational technologies in the field to massive data-management pathways. This is where cybersecurity efforts now need to be focused so that machinery and objects are protected from manipulation and potential compromise.

FIGURE 2. The increased availability of process data has significantly raised the bar for productivity and efficiency, but use of these digital technologies can also expose companies to cyber-crimes

The highly organized nature of espionage malware is of special concern. For example, Careto (or "The Mask" when translated from Spanish) was discovered in 2014 and believed to target government bodies. More recently, The Mask has been directed at energy companies, and another such threat, known as the Phantom Menace, aimed to compromise the control systems of a marine vessel by stealing data. Malware can remain in the background and run unknown, and then pop up when triggered at a certain time or by an event. Malware has been used historically for stealing confidential data or taking over communication systems and using them as a backdoor to gain access to other systems.

Alongside the increased threat and heightened profile, antivirus software products struggle to keep up. Most virus checkers search for and detect only the most common viruses and malware. It is critical for industries to re-evaluate and further develop those systems for the protection of important assets and infrastructure.

Indeed, cybersecurity is still at an early stage of development across many industries, and not enough is known about the sources and frequency of attacks. Of course, responses and capabilities vary, with some companies committing resources and focus to advancing in this area. Other — usually smaller — companies lack the scale required to develop and affect solutions, so they will look to external sources.

However, the policies and strategies being developed by the E.U., U.K. and U.S. governments on how to manage and control cybersecurity will hopefully help companies to evolve. Industry regulators for each sector of industry have worked to generate policies or directives based on information from strong participants in the cybersecurity community. Each policy specifically addresses infrastructure concerns that are relevant to that region's citizens. It will take constant effort in perpetuity to ensure a company's infrastructure stays as secure and stable as possible. Even if present policies may be sufficient for current known threats, enhanced planning for long-term diligence should be the next immediate effort.

Connectivity equals vulnerability

The increasing digitalization of the energy, chemicals and marine industries has elevated the risk associated with cyberattacks, because hackers can now access data and systems from the outside.

In addition to hardware-based

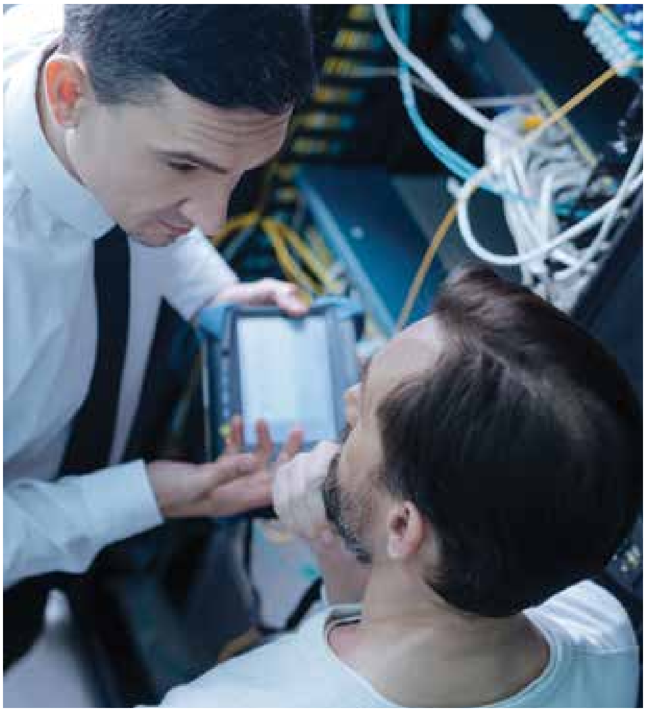

FIGURE 3. Comprehensive cybersecurity training and practical demonstrations can decrease inadvertent human error, which is one of the main enablers of successful cyberattacks

threats, software presents a different type of risk. A software tool may be tied into a company's vulnerable information, which could be, for example, a data-logging entity, the drilling control system of an oil rig or even a company's financial information. So, if a cyber attacker gained access through the physical elements (such as ports, servers and so on), now they have access to a company's financial data — just by inserting a push email. Using a simple email, a virus can embed itself into metadata and continue to spread. In this instance, the very specific nature of the virus means that it is unlikely to be detected by antivirus software.

Knowledge-sharing is a defense

Cybersecurity skills are vital for today's industry. This means training or investing in specialist, as well as operational, teams, so that actions and processes are thoroughly considered in the context of cybersecurity. Comprehensive procedures to help companies tackle cybersecurity issues may include a complete overview of the systems, equipment and personnel at a particular facility and a means of evaluating which elements are most vulnerable to attacks and then comparing their condition to international and regional standards.

Most cyber threats today gain access to operational systems via connected personal and professional computers. The most effective way for future protection of critical infrastructure is to combine efforts and resources to quickly identify common platforms for machine learning and edge computing that will remove the need for human connectivity to operational technology systems.

Additionally, unintentional potential breaches of cybersecurity are common. There have been several notable examples where a USB drive is supposed to be scanned before it goes into any system at a petroleum refinery or other facility. A person may use the drive, then pass it to the next person, and so on and plug it into various systems or devices. This is obviously not secure, but the practice continues, since using USB drives has been the routine practice over and over for third parties, contractors, equipment manufacturers and others.

For this reason, an assessment should always include human and social factors, as well as technical, process and equipment aspects. This includes gaining a deep understanding of how people actually behave, rather than assuming that policy and procedure will manage the reality.

Awareness through training

The 2018 Global State of Information Security Survey conducted by PricewaterhouseCoopers (PwC) found that current employees remain the top source of security incidents. Further, it is estimated that upwards of 90% of successful cyberattacks continue to succeed because of human error — the unwitting actions of anyone in any role within an organization.

This is why an attitude of "awareness through training" is essential (Figure 3). Companies must work with their personnel and engage in conversations with them about the threats that are out there. More-effective employee training is a key factor in reducing the occurrence of cyberattacks and the costs of dealing with breaches after they occur.

Companies may employ an interactive learning plat-

FIGURE 4. No sector of industry is immune to cyberattacks, and cyber criminals will continue to tailor their skills to match trends in digital technologies. But companies can equip themselves with the knowledge and awareness to take proactive measures to safeguard their assets

form that allows them to tailor content to suit their employees and specific critical cyber risks. Ideally, such a training platform requires no complex integration, and includes the option for employees to also access the content remotely for increased flexibility.

Also available are diagnostic tools that can assess employees' existing levels of security knowledge and build personalized learning pathways. This allows companies to provide the modules they think are necessary for different roles and levels of knowledge. This tailored approach, together with regular built-in assessments, ensures maximum training effectiveness, increases employee engagement and improves operational efficiency.

Comprehensive training can help to align people, processes and technology with their company's priorities and risks, including threat intelligence, governance, risk and compliance, security testing, training and strategy, managed security services and incident response. Understanding the risk environment of the digital world can help to identify gaps in systems, as well as knowledge gaps with inexperienced employees, and bring awareness and resilience for cyber threats to businesses.

What will be the new norm?

What is on the horizon for the cyber world? Cyber-domain experts are seeing a lot of new trends; specific areas that are evolving include increased exposure due to internet of things (IoT) technologies, increased ransomware attempts and expanded regulations. Ransomware attacks may threaten to release sensitive information unless terms are met or a certain price is paid to the attacker.

Globally, nations and governments are responding to higher levels of cyber-threat mitigation. For example, Singapore's Minister for Communications and Information recently introduced a new standalone Cybersecurity Act. Singapore is reviewing the policy and legislative framework for cybersecurity. The Cybersecurity Act reflects the Singapore government's calibrated and balanced approach towards countenancing cybersecurity threats. It is borne out of an attempt to strike a balance between the need for regulatory authorities to designate, investigate and receive information on critical information infrastructure and cybersecurity threats vis-à-vis the burdens imposed on companies and private individuals in the IT industry.

Cyber risks are rising, and society's technological advances appear to contribute to their proliferation. Experts suggest that beyond industrial threats, the number of cyber incidents involving geo-location systems may cause disruptions in energy supply chains and shipping, as well as risks to consumers who are reliant on GPS-based products. Furthermore, as bitcoin and other cryptocurrencies become more widely adopted, experts expect to see more frequent and severe ransomware campaigns.

Clearly, no organization — or for that matter, nation — can afford to ignore the potential impacts of cyber threats and attacks (Figure 4). No sector of the economy is immune from attack, whether it be industry, government or the not-for-profit sector. The best effort is a change in mindset, particularly between government and industry, emphasizing collaboration. Staying ahead of the advancements in technology, and keeping open communication channels for potential capabilities to access any vulnerability in any part of an operation or a company's supply chain, will be critical. A more open and rapid transfer of threat information from both public and private sectors is the best way for everyone to keep progressing with threat mitigation. While cyber criminals become more sophisticated, so too must our response and proactive defensive measures. ■

Edited by Mary Page Bailey

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Fluid Sealing

special advertising section

Inside:

Fluid sealing can be extremely difficult in harsh conditions.

Abrasion, strong chemicals, high temperatures and irregular surfaces can all contribute to leaks and short seal lifespans.

A few of the many DeWAL PTFE and UHMW films and tapes used for gaskets, expansion joints, valves and diaphragms.

To prevent seal failure in these conditions, **DeWAL** has developed more than a dozen durable, bondable PTFE and UHMW film and tape compositions for gaskets, expansion joints, valve seals and diaphragms.

Some examples:

DW601. DW601 is a fiber-filled PTFE tape in a number of thicknesses. It combines flexibility with very good deformation in load-carrying situations and is used for running against hard mating surfaces like cold-rolled steel.

DW602. With a low coefficient of friction and reliable product stability at very high temperatures, DW602 is a specially filled PTFE compound coated with a silicone adhesive. It is specified for many seal applications. Strong, lube-free, dynamic and durable, it is resistant to deformation under load.

DW611. A filled PTFE compound with special grades of carbon graphite, this black tape exhibits low friction and excellent wear properties in watery applications.

Dynaglide 633. For seals, gaskets or sliding bearings, this is one of many Dynaglide PTFE tapes with excellent friction and abrasion properties and is used on many different soft mating substrates. It is often used to prevent wear on painted surfaces

DW203. DW203 is an unsintered PTFE film used primarily for electrical insulation. It is fibrilated for high strength in the machine direction and is chemically inert, even in extreme temperatures. With notable drape characteristics, it is used for gaskets, expansion joints, valve seals and diaphragms.

DW134. DW134 is a series of PTFE impregnated glass fabric tapes. The PTFE provides a smooth anti-stick surface while the glass fabric provides extra strength and dimensional stability. In a range of widths and thicknesses, DW134s are all coated with a high temperature silicone adhesive.

DW232p. DW232p is ideal for venting gases when holding liquids, for separating oil and water, for gasketing and for filtering where high temperatures and caustic chemicals are present. It is a dimensionally stable, crush resistant, low density porous skived PTFE.

DW 402p & 402hp. Micro-porous, **DW 402p** is specified for gas and liquid filtration, medical test kits, wicks, and low dielectric constant wrap. Even stronger and more porous, **DW402hp** is excellent for liquid and air filtration, vents, diagnostics, wicks and support media for finer membrane structures. Both UHMW films are chemically inert and can be hydrophilic or hydrophobic.

DeWAL, part of Rogers Corp., has designed and manufactured PTFE and UHMW films and tapes in its RI facility since 1974.

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Customized sealing and safety solutions for all agitated processes by EKATO

EKATO's offer: Engineered solutions and consulting to sealing requirements for your agitated processes

- Customized sealing solution for best process safety and optimum MTBF containment
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EKATO is one of the pioneers in using mechanical seals in agitator technology and has its own mechanical seal production. Since many years EKATO advances the technology continuously, always regarding the requirements of the agitated processes and the safety philosophy of the customers. The EKATO Brand ESD is a synonym for customized sealing solutions in highest quality.

EKATO offers consulting in questions concerning sealing technology for:

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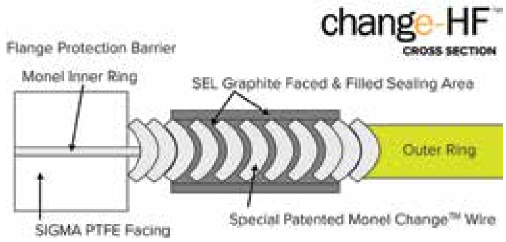
Gasket Technology 100 Years In The Making

Flexitallic invented the spiral wound gasket over 106 years ago; the Change gasket is their next generation of sealing technology.

The Change gasket has become the most significant development in the gasket and sealing industry in the past five years with more than 100,000 gaskets sold around the world into sectors such as Steel, Power, Chemical, Refining, and Pulp & Paper. Developed by Flexitallic in direct response to customers' long-term heat exchanger sealing problems, the Change gasket is a highly-resilient metal-wound gasket, designed to deliver the most dynamic static sealing technology ever. Manufactured using proprietary equipment, the Change gasket has a proven track-record showing it outperforms conventional gasket technology in challenging environments, especially in applications with mechanical and thermal cycling conditions. It has also achieved independent industry accreditation from TA Luft for its ability to deliver the tightness of a Kammprofile with the recovery of a spiral wound gasket. This is achieved through the application of a unique metal spiral profile, which is more advanced than those found in standard gaskets. This profile, combined with a laser welding process, facilitates the construction of a robust and dynamic seal. The unique wire profile stores more elastic energy to create better dynamic performance and superior load retention in cyclic applications. This leads to excellent recovery (tested with 34% recovery @ 18K PSI [124 MPa], 30% compression). With these dynamic characteristics, there is no need for spring washers or re-torquing. This allows the gasket to cycle over & over, and maintain sealability. Furthermore, from the Change gasket design, a new corrosion-resistant family of Change gaskets was born; Change-HF (HF Alky applications), Change-SF for (Sulfuric Acid applications) and the Change-CR (other corrosive applications). The Change-HF is constructed like a standard Change gasket, but includes an inner ring barrier (monel, faced with Sigma PTFE) that protects the flange from acid corrosion and also fills any existing corrosion damage. The sealing portion consists of a special patented Monel

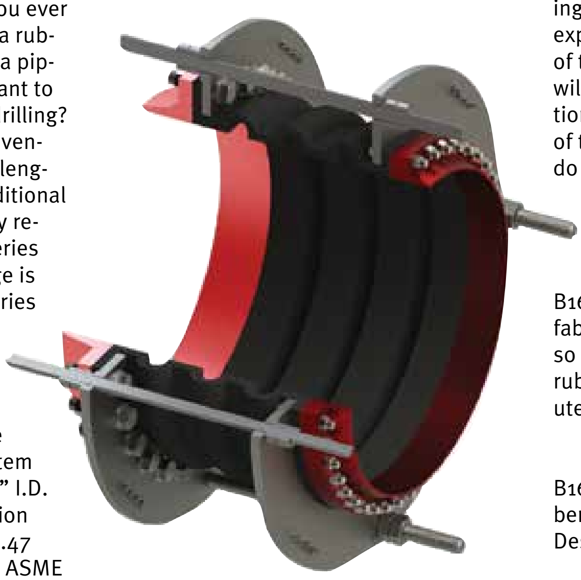


Change wire with graphite facing and filler. This Change gasket technology combined with the Sigma flange protection barrier allows the Change-HF to far outperform other similar gaskets on the market. The Change gasket has had much success including being selected as the replacement gasket for a major national refiner; switching all of their HF-Alky gaskets to the Change-HF. The Change gasket along with the Corrosion Protection product line offers the newest and best-in-class innovations solving their customers' sealing challenges now and well into the future. For more information on the Change gasket, visit

www.Flexitallic.com/change

How Do I Account for ASME B16.47 Series B Drilling When Specifying a Rubber Expansion Joint?

Piping System Designers: Have you ever come across the need to supply a rubber expansion joint/control units in a piping system where the flanges you want to attach have ASME B16.47 Series B drilling? If so then you will know that the conventional control rod set up can be challenging as the attachment area for a traditional triangular control rod plate is greatly reduced. With ASME Series B16.47 Series B Drilling the bolt circle for the flange is closer to the I.D. of the pipe than Series A drilling.



So what design can be used for ASME B16.47 Series B drilling?

The best rubber expansion joint design to consider is an "Interior Tie Rod" design. In this example, a system designer has an application for a 30" I.D. X 24" OAL triple arch rubber expansion joint with one end having ASME B16.47 Series A drilling and one end having ASME B16.47 Series B drilling. Control rods are used in this example as the piping system is unrestrained. The use of an "Interior Tie Rod" design where a thicker ring/rod plate connects the rubber expansion joint to the adjacent mating flange while containing the thrust loads and movement of the expansion joint under pressure (with use of the connecting rods). Using this design will eliminate the complication of a traditional control rod set up on the back side of the mating flange where the rod plates do not have enough webbing from the I.D. of the plate to the I.D. of the holes on an ASME B16.47 Series B flange.

The only other option a client might have when dealing with ASME B16.47 is a control rod set up where thick fabricated split flange plates are supplied so that the resultant thrust loads from the rubber expansion joints are evenly distributed to every bolt hold.

In conclusion the best design for ASME B16.47 Series B bolting when using a rubber expansion joint is the Interior Tie Rod Design configuration.

www.procoproducts.com

Teadit®'s Origin™ RC510 Gasket technology has been awarded America's First Prize for the 2018 Plunkett Award by Chemours™

These awards recognize advancements in products and applications across the Chemours™ fluoropolymer portfolio, including Teflon™ fluoropolymers, which Teadit® uses in their Tealon™ under a Chemours™ license.

The Plunkett Awards are named after Dr. Roy Plunkett who discovered fluoropolymers 80 years ago. "The Plunkett Awards recognize our customers and their commitment to using the power of chemistry to create industry-defining solutions to many of society's most complex and evolving needs," said Paul Kirsch, president, Chemours™ Fluoroproducts. "Businesses must innovate, driving the development of more sustainable, higher performing products to keep pace with a rapidly changing world. At Chemours™, we're proud to partner with our customers to deliver innovative solutions that address the needs of today and the challenges of tomorrow." Entries were judged by a panel of regional experts who evaluated the submissions for their degree of innovation, sustainability impact, breadth of use, and commercial significance.

It's not often that a new gasket design is introduced to the sealing world. **Teadit**®'s Origin™ RC 510 gasket is a new, and unique product, produced utilizing a new, revolutionary and patented technology – The Origin™ Process. This design was developed with the challenges of rail car service in mind, while utilizing Teadit®'s Tealon™ restructured, and filled, PTFE material. It is designed to incorporate all of the best features of gasket products and properties that make for an effective seal, while being both easy to use and easy to install.

Teadit®'s Origin™ process eliminates wasteful consumption of material by dramatically reducing scrap generated from traditional gasket cutting processes through winding Teadit® Tealon™ PTFE tape into a final ID/OD, thus decreasing its environmental footprint. During the manufacturing process almost 100% of the raw materials are used, which helps to make PTFE practical and affordable. Finally, Teadit®'s Origin™ RC510 provides outstanding sealing characteristics similar to an elastomeric design, except it provides the superior chemical resistance, reliability and durability of PTFE. **www.teadit.com**

Economic Indicators

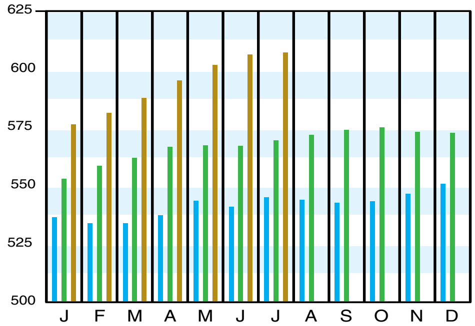
2016 2017 2018

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	July '18 Prelim.	June '18 Final	July '17 Final
CE Index	607.3	605.2	569.6
Equipment	740.1	738.1	686.7
Heat exchangers & tanks	656.2	654.0	603.6
Process machinery	724.3	716.9	685.9
Pipe, valves & fittings	966.5	967.7	876.6
Process instruments	422.7	427.9	403.9
Pumps & compressors	1025.8	1017.9	984.7
Electrical equipment	538.0	536.2	520.8
Structural supports & misc.	809.9	805.3	739.9
Construction labor	335.6	332.3	330.4
Buildings	602.5	600.8	561.7
Engineering & supervision	308.1	307.3	313.3

Annual Index:
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5

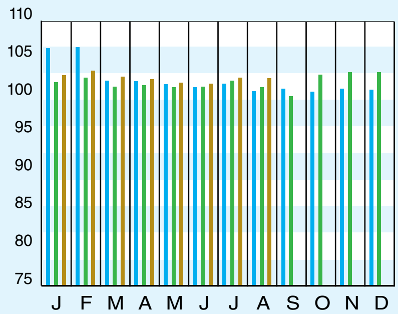


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

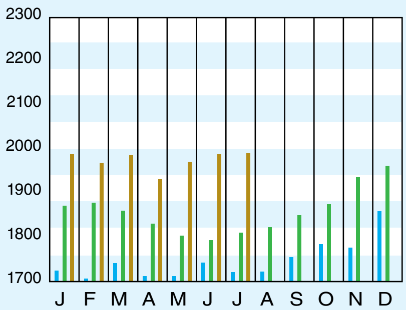
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Aug. '18 = 102.4	Jul. '18 = 102.7	Jun. '18 = 102.2	Aug. '17 = 99.5
CPI value of output, $ billions	Jul. '18 = 1,992.3	Jun. '18 = 1,989.0	May '18 = 1,973.6	Jul. '17 = 1,762.4
CPI operating rate, %	Aug. '18 = 76.2	Jul. '18 = 76.5	Jun. '18 = 76.1	Aug. '17 = 74.9
Producer prices, industrial chemicals (1982 = 100)	Aug. '18 = 279.1	Jul. '18 = 277.8	Jun. '18 = 273.9	Aug. '17 = 252.8
Industrial Production in Manufacturing (2012 =100)*	Aug. '18 = 104.6	Jul. '18 = 104.3	Jun. '18 = 104.0	Aug. '17 = 101.4
Hourly earnings index, chemical & allied products (1992 = 100)	Aug. '18 = 183.0	Jul. '18 = 183.4	Jun. '18 = 183.8	Aug. '17 = 177.3
Productivity index, chemicals & allied products (1992 = 100)	Aug. '18 = 96.6	Jul. '18 = 96.7	Jun. '18 = 96.8	Aug. '17 = 96.9

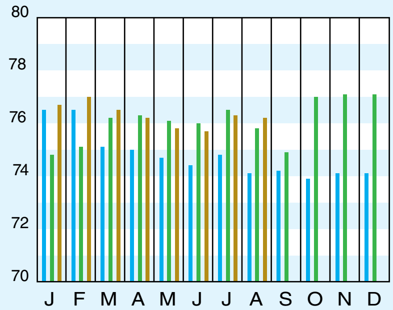
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the July 2018 *CE* Plant Cost Index (CEPCI; top; most recent available) increased slightly compared to the previous month's value, although, due to revisions in the values, the final June value was adjusted downward by a small amount. All four of the major subindices — Equipment, Buildings, Construction Labor and Engineering & Supervision — moved higher for July by modest amounts. The overall CEPCI for July stands at 6.6% higher than the corresponding value from July of last year. The year-over-year percentage difference for July was smaller than that of June, reversing a trend of increasing year-over-year differences since the beginning of 2018. In the CBI (middle), the CPI output index fell in August.